Science Library

133

JAN 21 1938

VOLUME 28 NUMBER 1

JANUARY, 1938

Phytopathology

An International Journal

Official Organ of

The American Phytopathological Society

CONTENTS

Abstracts of papers accepted for presentation at the Twenty-eighth Annual Meeting of the Society, Indianapolis, Indiana, December 27 to 30, 1937 1

Gall development on Pinus sylvestris attacked by the Woodgate Peridermium, and morphology of the parasite ..... R. P. True 24

Failure of Dasyscypha willkomnii and related large-spore species to parasitize Douglas fir.
Glenn Gardner Hahn and Theodore T. Ayers 50

Taxonomic relationships of plants susceptible to infection by tobacco-mosaic virus ..... Francis O. Holmes 58

Additional studies concerning the rust of iris, Puccinia iridis.
E. B. Mains 67

Phytopathological Notes 71

Blueberry galls produced by the fungus Phomopsis.
Nellie A. Brown

Elsinoë on lemon fruits from Paraguay ..... Anna E. Jenkins

An Elsinoë causing an anthracnose on Hicoria pecan.
Anna E. Jenkins and A. A. Bitancourt

Gill fungi associated with the roots of cereals ..... Roderick Sprague

Price { $6.00 per year, United States and dependencies,
$6.25 per year, Canada
$6.50 per year, elsewhere

PUBLISHED MONTHLY BY THE SOCIETY

OFFICE OF PUBLICATION

Cor. Lime and Green Streets, Lancaster, Pa.

Entered at the postoffice in Lancaster, Pa., as second-class matter.

DIRECTORY OF ADVERTISERS

AMERICAN POTASH INSTITUTE, Investment Building, Washington, D. C.	A NEW SERVICE ORGANIZATION ON THE USE OF POTASH IN CROP PRODUCTION
BAYER SEMESAN CO., INC., Du Pont Building, Wilmington, Del.	SEED AND SOIL TREATMENTS. NEW IMPROVED CERESAN. NEW IMPROVED SEMESAN JR.
BAUSCH & LOMB OPTICAL CO., 665 St. Paul St., Rochester, N. Y.	MICROSCOPES. MICROTOMES.
JOHN BEAN MFG. CO., Division Food Machinery Corp., Lansing, Michigan.	SPRAYING, DUSTING, GRADING, CLEANING, AND WASHING EQUIPMENT.
CENTRAALBUREAU VOOR SCHIMMELCULTURES, Baarn, Netherlands.	FUNGUS CULTURES FOR USE IN RESEARCH AND TEACHING
CHICAGO APPARATUS CO., 1735 1743 N. Ashland Ave., Chicago, Ill.	SCIENTIFIC INSTRUMENTS, LABORATORY SUPPLIES, AND CHEMICALS.
CLAY ADAMS CO., 25 East 26th St., New York, N. Y.	SLIDE AND COVER GLASSES. MICROSCOPIC PROJECTION AND DRAWING APPARATUS.
DIFCO LABORATORIES, 920 Henry St., Detroit, Mich.	DEHYDRATED CULTURE MEDIA.
THE GRASSELLI CHEMICAL CO., Cleveland, Ohio.	SPRAY MATERIALS AND DUSTS.
HAMMOND PAINT & CHEMICAL COMPANY, Ferry Street, Beacon, New York.	FORMACIDE FORMALDEHYDE DISINFECTANT.
MESSINGER MFG. CO., Tatamy, Pa.	CROP DUSTERS, THRESHERS AND CORN SHELLERS.
THE MOUNTAIN COPPER CO., LTD., 351 California St., San Francisco, Calif.	COPPER CARBONATE, CUPROS OXIDE AND OTHER COPPER FUNGICIDES AND INSECTICIDES.
NIAGARA SPRAYER AND CHEMICAL CO., INC., Middleport, New York.	DUSTERS, DUSTS, AND SPRAYS. KOLOFOG, POMO-GREEN.
B. G. PRATT CO., 50 Church St., New York, N. Y.	SPRAY CATALIZER FOR LIQUID AND DRY LIME SULPHUR.
ROHM & HAAS & CO., INC., 222 W. Washington Square, Philadelphia, Pa.	RED COPPER OXIDE. FORM-O-FUME FORMALDEHYDE DUST.
THE R & H CHEMICALS DEPT., E. I. Du Pont de Nemours & Co., Inc., Wilmington, Del.	P. A. C. FORMALDEHYDE.
THE SCIENCE PRESS PRINTING CO., Lime and Green Sts., Lancaster, Pa.	PRINTERS OF SCIENTIFIC JOURNALS, BOOKS AND MONOGRAPHS.
TRIARCH BOTANICAL PRODUCTS, Geo. H. Conant, Ripon, Wis.	PRESERVED PLANTS. MICROSCOPE SLIDES.
THE STAUFFER CHEMICAL CO., 420 Lexington Ave., New York, N. Y.	SULPHUR FUNGICIDES. DUSTING AND SPRAY SULPHURS.
VIRGINIA SMELTING COMPANY, West Norfolk, Virginia.	SEED TREATMENT "VASCO 4."

PHYTOPATHOLOGY

An International Journal

Official Organ of The American Phytopathological Society

EDITORS

H. B. Humphrey, Editor in Chief, U. S. Department of Agriculture, Washington, D. C.
H. M. Quanjer, Editor for Europe, Instituut voor Phytopathologie, Wageningen, The Netherlands.
Wm. W. Diehl, U. S. Department of Agriculture, Washington, D. C.
C. E. Owens, Oregon State College, Corvallis, Ore.

ASSOCIATE EDITORS

George H. Hepting, Asheville, N. C.
Freeman Weiss, U. S. Hort. Field Station, Beltsville, Md.
R. W. Goss, University of Nebraska, Lincoln, Neb.
C. J. Eide, University Farm, St. Paul, Minn.
Jocelyn Tyler, U. S. Department of Agriculture, Washington, D. C.
Edna Buhrer, U. S. Department of Agriculture, Washington, D. C.
Camille L. Lefebvre, U. S. Department of Agriculture, Washington, D. C.
T. E. Rawlins, University of California, Berkeley, Calif.
Geo. F. Weber, University of Florida, Gainesville, Fla.
Thorvaldur Johnson, Dominion Rust Research Laboratory, Winnipeg, Canada.
A. J. Riker, University of Wisconsin, Madison, Wis.
W. J. Zaumeyer, U. S. Horticultural Field Station, Beltsville, Md.

BUSINESS MANAGEMENT

H. A. Edson, Business Manager, U. S. Department of Agriculture, Washington, D. C.
R. S. Kirby, Advertising Manager, Pennsylvania State College, State College, Pa.

NOTICES

All communications regarding subscriptions and back numbers should be sent to H. A. Edson, Business Manager Phytopathology, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

Subscription price. $6.00 per year United States and dependencies; Canada $6.25; other countries $6.50; current single numbers 60 cents. The journal is issued monthly beginning with Volume VIII, January, 1918.

Back Volumes IX to XXVI inclusive (except Vol. IX, No. 1, which is not available) unbound at $8.00 per volume. All earlier volumes obtainable only in broken numbers.

Separate Numbers will be supplied from broken volumes only, when the supply becomes low. Separate numbers from Volumes IX to XXVI, $1.00 per copy; from Volumes I to VIII, $2.00 per copy. The following numbers of Volumes I to VIII, inclusive, are obtainable: Volume I, Nos. 1, 4, 6 and index; Vol. II, Nos. 1, 4, 5 and index; Vol. III, Nos. 4, 5; Vol. VI, index only; Vol. VIII, Nos. 2 to 12 and index.

Requests to supply copies of the journal must be made within 60 days from date of issue. Date of issue January 15 and monthly thereafter.

Advertisements. Rates may be secured from the Advertising Manager. No indorsement of any statement of claims made in advertisements is assumed by this journal or by The American Phytopathological Society.

The American Phytopathological Society

FOUNDED 1909. INCORPORATED 1915

Officers for 1938

H. W. ANDERSON, President (1 yr.), University of Illinois, Urbana, Ill.

R. W. GOSS, Vice-President (1 yr.), University of Nebraska, Lincoln. Neb.

R. S. KIRBY, Secretary (3 yrs. Term expires 1940), Pennsylvania State College, State College, Pa.

H. A. EDSON, Treasurer and Business Manager of PHYTOPATHOLOGY (3 yrs. Term expires 1940), U. S. Department of Agriculture, Washington, D. C.

H. B. HUMPHREY, Editor in Chief of PHYTOPATHOLOGY (3 yrs. Term expires 1940), U. S. Department of Agriculture, Washington, D. C.

Councilors for 1938

G. W. KEITT (Term expires 1938), University of Wisconsin, Madison, Wis.

CHAS. CHUPP (Term expires 1938), Cornell University, Ithaca, N. Y.

J. J. CHRISTENSEN (Term expires 1939) University of Minnesota, St. Paul, Minn.

G. F. WEBER (1 yr. for the Southern Div.), University of Florida, Gainesville, Fla.

J. W. HOTSON (1 yr. for the Pacific Div.), University of Washington, Seattle, Wash.

Representatives for 1938

A. A. A. S. Council (1 yr.), W. D. Valleau, S. A. Wingard.

Elector Group V, Division of Biology and Agriculture, National Research Council (Terms expire 1940), E. C. Stakman (H. P. Barss, alternate).

Board of Governors, Crop Protection Institute (3 yrs.), Kenneth Kadow (Term expires 1939), C. R. Orton (Term expires 1938), J. G. Horsfall (Term expires 1940).

Tropical Research Foundation (5 yrs.), L. R. Jones (Term expires 1940).

International Union of Biological Sciences, A. G. Newhall.

Board of Editors, American Journal of Botany, G. W. Keitt (3 yrs. Term expires 1940).

Union of American Biological Societies (and Biological Abstracts), H. B. Humphrey and R. S. Kirby (*ex officio*), G. W. Keitt, H. A. Edson, D. Reddick, H. P. Barss.

Standing Committees for 1938

Regulatory Work and Foreign Plant Diseases. C. R. Orton, Chm., H. T. Güssow, J. S. Boyce, W. A. McCubbin, R. D. Rands, J. F. Adams, E. L. Chambers.

Extension Work and Relations. Luther Shaw, Chm., Chas. Chupp, R. J. Haskell, S. L. Pierstorff, R. S. Kirby, E. C. Stakman, G. W. Keitt, W. B. Tisdale, I. L. Conners.

Coordinaton in Seed Treatment Research. C. S. Reddy, Chm., W. E. Brentzel, M. B. Moore, H. A. Rodenhiser.

Phytopathological Classics. H. H. Whetzel, Manager; H. B. Humphrey, Editor.

Necrology. A. G. Johnson, Chm., M. B. Waite.

Investments. H. A. Edson, Chm., N. E. Stevens, Chas. Brooks, F. C. Meier, J. W. Roberts.

Donations and Legacies. F. C. Meier, Chm., E. C. Stakman, N. E. Stevens, J. G. Brown, N. J. Giddings.

New Memberships and Subscriptions. A. J. Riker, Chm., Kenneth Kadow, R. M. Lindgren, B. A. Rudolph, R. S. Kirby (*ex officio*).

YOUR ADVERTISING MANAGER SUGGESTS

that we let you know that we are the Manufacturers of the following:

Kolodust (the fused Bentonite Sulphur dusts)—with and without poisons
Kolofog (the fused Bentonite Sulphur spray)
Emulso (oil emulsion)
Tar-E-Mul (Tar Oil Wash)
Arsenate of Lead **Suspenso Lead Arsenate** **Calcium Arsenate**
Copodust **Copotex**
Pink Kolodust (for dusting peaches in the packing house)
Pomo-Green (with and without Nicotine)
Rotenone Dusts and Sprays

Also that we manufacture all standard *insecticides* and *fungicides*, and *dusting* and *spraying machinery*.

WHEN YOU BUY Niagara YOU BUY PROTECTION

NIAGARA SPRAYER and CHEMICAL CO., INC.
Middleport, N. Y.

REAGENTS AND STAINS

CHEMICAL

★ In selecting your chemical reagents and stains why gamble your valuable time against the uncertainties of unknown brands? Insist upon those of reputable manufacturers by ordering from the Chicago Apparatus Company's stock of such products. Lower grades come in screw-capped glass containers, filled under close supervision from the original manufacturers' containers. Higher grades are in their original containers. For complete listing see our Catalog No. 45.

Chicago Apparatus Company
Science Laboratory Equipment
1735 NORTH ASHLAND AVENUE • CHICAGO U. S. A.

TRIARCH BOTANICAL PRODUCTS

Do You Know—

That Triarch stocks the largest available collection of preserved specimens and prepared microscope slides for Plant Pathology?

That Triarch Products are used in over 400 colleges and universities?

That pathologists may send us their own collections to be worked up into prepared microscope slides at moderate prices?

Look into these possibilities by sending for our catalog:

Address

Geo. H. Conant
Ripon, Wisconsin

STAUFFER

Stauffer CHEMICALS

"Anchor" Brand Sublimed Velvet Flowers of Sulphur

"Magnetic Spray" Wettable Sulphur

"Electric" Super-Adhesive Dusting Sulphur

"Perfection" Brand Dusting Sulphur

"Crown" Brand Wettable Sulphur

"Toro" Brand Activated Soil Sulphur

"Swan" Brand Superfine Ventilated Dusting Sulphur

"Owl" Brand Superfine Commercial Dusting Sulphur

"Triangle" Brand Commercial Flour Sulphur

"Magnetic" Catalytic Sulphur

"Magnetic" Rotenone-Sulphur Dust

"Magnetic" Pyrethrum-Sulphur Dust

"Magnetic" Cryolite-Sulphur Dust or Spray

"Magnetic" Cryolite Dust.

STAUFFER CHEMICAL COMPANY

Chicago, Ill. 420 Lexington Ave., New York, N. Y. Freeport, Texas.

SULPHURS

DIFCO

Culture Media for Fungi

This group of Dehydrated Culture Media, Difco, is prepared expressly for the laboratory propagation of the fungi which are most frequently encountered in phytopathological studies. The media are readily made up for use and require neither adjustment of their reaction nor filtration of the solution.

Bacto-Corn Meal Agar
Bacto-Prune Agar
Bacto-Potato Dextrose Agar
Bacto-Bean Pod Agar
Bacto-Lima Bean Agar
Bacto-Malt Extract Agar (Synthetic).

Specify "DIFCO"

THE TRADE NAME OF THE PIONEERS
In the Research and Development of Bacto-Peptone and Dehydrated Culture Media

DIFCO LABORATORIES
INCORPORATED
DETROIT, MICHIGAN, U. S. A.

ABSTRACTS OF PAPERS ACCEPTED FOR PRESENTATION AT THE TWENTY-EIGHTH ANNUAL MEETING OF THE SOCIETY, INDIANAPOLIS, INDIANA, DECEMBER 27 TO 30, 1937[1]

A New Tomato Variety Resistant to Leaf Mold. L. J. ALEXANDER. The new variety, Globelle, is the result of a breeding program carried through 14 generations since its inception in 1930. The parents of the original cross are Globe, *Lycopersicum esculentum*, and Red Currant, *Lycopersicum pimpinellifolium*. Four additional crosses to the type varieties, Globe and Marhio, were necessary. Six generations have elapsed since the last cross. The growth habits of Globelle are similar to those of Globe, but differ in that the leaves hang closer to the plant and tend to be smaller. The fruits are pink, the same as Globe, but the quality is superior, and a larger percentage of fancy grade is produced. Data on yield and quality will be presented. What appeared to be a factor for a partial lethal was observed in the F_2 generation of the original cross. Subsequent observations indicate that this factor is linked with the Cf_{p1} resistant factor. Evidence was found also that linkage exists between the resistant factor and small fruit size. This year occasional leaf-mold lesions were observed on heavily fruiting plants of resistant lines, whereas Globe plants in the same test were almost completely defoliated, and, as a consequence, were producing small fruits of poor quality.

Physiologic Specialization of Thielaviopsis basicola on Tobacco. C. C. ALLISON. Seeds of various varieties of tobacco, including Burley and flue-cured types, were sown in flats containing soil artificially infected with single-spore cultures of *Thielaviopsis basicola*. Four definite physiologic races were determined on the basis of their pathogenicity on 4 tobacco varieties: Special 400, Kentucky No. 5, Kentucky No. 16, and Harrow's Velvet. Kentucky No. 5 was moderately susceptible to race 1, while the other varieties were resistant; Kentucky 5 and Special 400 were moderately susceptible to race 2, and Kentucky No. 16 and Harrow's Velvet were resistant. Kentucky No. 5 and Special 400 were susceptible, Kentucky No. 16 was moderately susceptible, and Harrow's Velvet was resistant to race 3. Harrow's Velvet was moderately susceptible to race 4, while the other 3 varieties were susceptible. Races 1 and 2 were isolated from specimens of black root rot obtained from Tennessee and North Carolina. Race 3 was isolated from material obtained from Tennessee and Washington, D. C. Race 4 was isolated from specimens sent from Wisconsin and Canada.

Studies on Inheritance of Resistance to Wilt in Flax. C. C. ALLISON and J. J. CHRISTENSEN. From 1934 to 1937 the inheritance of resistance to wilt (*Fusarium lini*) was studied in the progeny of 56 crosses involving 18 varieties of flax. When grown on flax-sick soil these varieties differed markedly in their susceptibility, the percentage of wilted plants varying from 5 to 100. In general, the F_1 crosses were intermediate between the two parents in resistance, although in certain crosses susceptibility or resistance appeared to be dominant. Types of segregation observed in F_2, F_3, and F_4 indicate that several factors are involved. The number of factors conditioning resistance is difficult to determine because resistance is relative and is influenced profoundly by environmental factors. When Bison was used as the resistant parent the percentage of resistant segregates obtained usually was higher than when other varieties, equally resistant, were used. It is encouraging that some F_4 and F_5 progenies of crosses, especially those between Bison (resistant to wilt but susceptible to rust) and Newland (very susceptible to wilt but immune from rust), are resistant to both diseases and possess certain desirable agronomic characters.

Certain Internal Factors Associated with the Susceptibility of Strawberry Roots to Injury by a Species of Fusarium. EARL J. ANDERSON. Chemical studies of roots and crowns of strawberry plants (var. Howard 17), grown in the greenhouse under different fertilizer treatments, indicate a relationship between the amount of sugars, particularly sucrose, present in these parts and their relative susceptibility to injury by *Fusarium orthoceras* App. et Wr. var. *longius* (Sherb.) Wr. Microscopic examinations of comparable roots indicate quite clearly that the walls of cortical cells in roots relatively susceptible to injury by the fungus were thinner than in less susceptible roots. The data afford little evidence that growth rate of the plants, or other factors studied, except as mentioned above, had any influence on susceptibility.

The Relation of Some New Copper Fungicides to the Control of Cherry Leaf Spot (Coccomyces hiemalis). H. W. ANDERSON and K. J. KADOW. The new copper materials

[1] Abstracts arranged alphabetically according to author or senior author.

now on the market, plus a product known as "66a," were tested to determine their value as fungicides for the control of cherry leaf spot. The materials tested were Oxo Bordeaux, Basicop, Coposil, copper phosphate with lime and bentonite, Cupro K, Cuprocide 54, Copper Zeolite, 66a, Copper-Hydro 40, Bordeaux 34 with zinc sulphate and lime, and a special copper from the Niagara Sprayer and Chemical Company. Because of weather conditions prevalent in Illinois, the season was ideal for the development of cherry leaf spot and spray injury. The materials that gave satisfactory control of cherry leaf spot without causing commercially important spray injury were (concentrations in 100 gallons of water): Bordeaux 34 (1½ pounds) with zinc sulphate (½ pound) and lime (½ pound); Cupro K (2 pounds); and liquid lime sulphur (2 gallons). Through misunderstanding, both Oxo Bordeaux and copper phosphate were used at one-half recommended strengths. Neither material caused spray injury nor did it give satisfactory control of leaf spot, although only about 15 per cent of the leaves fell in the copper phosphate plot. Several of the materials controlled leaf spot but caused sufficient injury to fruit or leaves to necessitate "safening" before their use is advised.

Migration of Spores of Colletotrichum falcatum in the Tracheary Vessels of Sugar-cane Stalks. R. E. ATKINSON and C. W. EDGERTON. That spore migration in the tracheae might explain the longitudinal spread of red rot in inoculated sugar-cane stalks seemed probable when it was found that the rate of spread was as great as ½ inch an hour. In later experiments a spread of 2 to 3 feet in an hour has been observed. That it is possible for spores to migrate through tracheae has been demonstrated by drawing spore suspensions through cane stalks with a vacuum pump. Red rot in inoculated stalks appears as series of separate lesions along vascular bundles. Mycelial filaments were not observed in cross sections of bundles between lesions. *Colletotrichum falcatum* was obtained from 132 tissue transfers out of 180 made from lesions, but only from 11 out of 211 made from between lesions. In inoculation tests with mycelium alone, red rot has developed only in the areas immediately around the points of inoculation. In contrast, following inoculations with red-rot spores, lesions have occurred along vascular bundles for a distance of 2 to 3 feet.

Mint Anthracnose. R. C. BAINES. Anthracnose caused by *Sphaceloma menthae* occurs on peppermint and spearmint in Indiana. Severe infection causes defoliation and a blighting of young stems and stolons, and apparently causes significant losses. The disease was produced by artificial inoculations on white, black, and State peppermint, common and Scotch spearmint, and Japanese mint. In the necrotic tissue the mycelium is largely intercellular and sparsely distributed. The unicellular conidia are sessile on a superficial stroma. On malt extract, potato-dextrose, and Leonian's agar media, the fungus grows slowly and produces a brown heaped type of colony. The cultures grew well at temperature between 14° and 28° C., on media adjusted to pH values between 3.6 and 8.2. The temperature range of 21° to 26.8° C. was most favorable for infection and the development of the disease. The fungus overwinters on infected mint débris and is introduced into new fields on infected plants.

Phytophthora Trunk Canker of Apple. R. C. BAINES. Physiologic races of *P. cactorum* have been distinguished by differences in the pathogenicity of pure cultures of the fungus when inoculated on the trunks of 10- and 11-year-old Gano, Grimes, King, Northwestern Greening, Rome, Smokehouse, and Stark apple trees as differential varieties. Twenty-four other varieties of apple trees showed no differential characteristics, being resistant to infection. A culture from *Lilium candidum*—infected King, Rome, and Stark, one from lilac infected King, one from loquet infected Grimes, King, Northwestern Greening, Rome, and Stark. An atypical culture isolated from Grimes bark was pathogenic only on Gano. One culture, isolated from each of the sources, apple fruit, citrus, peony, pine, and snapdragon, was nonpathogenic on the 31 varieties of apple trees. Seven of the 8 cultures of *P. cactorum* isolated from bark cankers, 3 of the 4 cultures from apple fruits, 1 of the 2 cultures from peony, and 2 cultures isolated from soil were pathogenic on Grimes. The trunks of 2-, 3-, and 4-year-old Grimes were resistant to infection, while the trunks of 8- to 30-year-old trees were susceptible. Large branches were more resistant than the trunks.

Effect of Nitrogen on Inception and Development of Dutch Elm Disease on American (Moline) Elm. W. M. BANFIELD. Two-year-old trees, heavily pruned but not cut back, were grown in sand, manured repeatedly throughout one season. Thereafter, they were given daily applications of Shive's nutrient solution. From similar trees manure was withheld the first season. Thereafter, they were given daily applications of Shive's nutrient solution minus N. Part of the trees (A) were injected with *Ceratostomella ulmi* spores when new growth had developed the second year; the remainder (B) were injected

the third year. A: 12 per cent of the main-stem growth of 13 or 15 + N, 84 per cent of 10 − N trees died back within the year of injection. No wilt or die-back developed on any trees the second year after injection. B: 0.4 per cent of the branch growth of the 6 + N, 35 per cent of the 10 − N trees died back within the year of injection. Similar trees were cut back and grown with daily applications of complete nutrient solution, or the same minus nitrogen. They were injected the second season. Wilt developed very quickly on 51 of 54 + N trees. Within 17 days 88 per cent of their leaves were lost, 41 days after injection 93 per cent of their main-stem growth died back. Wilt developed extremely slowly on 40 − N trees. Six displayed wilt within 17 days, 34 within 76 days. By season's close 73 per cent of their main-stem growth died back. No wilt or die-back developed in control trees of any group.

The Relation of Sap Flow, Vessel Length, Spore Distribution to Development of Dutch Elm Disease in American Elm. W. M. BANFIELD. *Ceratostomella ulmi* spores, beer yeasts, India ink, and iron colloids were injected into 135 American elms during the growing season. One hour after injection *C. ulmi* was recovered up to 50 feet in five 60-foot trees and up to 62 feet in one 65-foot tree. The colloids used, $Fe_4(Fe(CN)_6)_3$, $Fe(Fe(CN)_6)_2$, FeOCl, could not be detected more than 10 feet above injection points in comparable trials. Beer yeasts were recovered 25 feet above injection points. India ink was observed to descend 36 feet below injection points in 6 minutes. *C. ulmi* was recovered 40 feet below injection points 1 hour after injection in trials on 2 trees injected 41 feet above the ground. The locus of major spore distribution in all cases was the ring of large spring vessels of the current season's growth sheath. All earlier rings were found closed by tyloses in the crown and top half of the bole of 75 trees examined. Root vessels were tylose-free. Maximum spore distribution in summer wood vessels was 15 inches. Spore distribution prior to leaf expansion in the spring was limited to a few inches. No spore distribution in new vessels occurred until their partition walls had disappeared. Ten days later first symptoms of disease appeared in naturally infected trees.

Persimmon Wilt. R. KENT BEATTIE and BOWEN S. CRANDALL. A hitherto unrecognized rapid-killing wilt of the native American persimmon has made its appearance in Tennessee, southeast of Nashville. The known area of infection, based on rather limited scouting, is small. It consists of local spots in a triangular area between Lebanon, Bradyville, and Columbia, Tennessee. Nearly all the infections are 1 to 2 years old and only 2 are 4 to 7 years old. Although the disease has not yet been associated with any one known abroad, it behaves like an introduced disease. Infected trees are conspicuous in early summer because of their wilted and discolored leaves. Brownish-black streaks are formed in the recent annual rings. A species of Cephalosporium, isolated, and grown in culture, has produced the disease on inoculation into American persimmon, and has been reisolated. Spores are produced in openings and cracks in dead trees and especially under loose bark, where they may be collected by spoonfuls. They are probably windborne. Other species of persimmon have not yet been tested for susceptibility. No remedy is known.

Illustrations of South American Elsinoë and Sphaceloma Diseases Known up to January, 1936. A. A. BITANCOURT and ANNA E. JENKINS. A recent general article on the diseases of plants caused by *Elsinoë* and *Sphaceloma* contained a section relative to the 13 members of the group found in South America. This section was accompanied by a synoptic table giving available literature citations or other records relative to this special group. Representative illustrations were not included in the published paper, that is, with one exception. Illustrations representative of all 13 diseases are, therefore, assembled here for convenience of reference in connection with the paper cited, or with subsequent reports of the 13 fungi, or diseases, or with the considerably larger number subsequently discovered in South America, particularly in Brazil. Certain additional notations are made relative to diseases known up to January, 1936.

Mechanical Transmission and Properties of the Potato Yellow Dwarf Virus. L. M. BLACK. Leaf-hopper-borne viruses have been transmitted mechanically only with difficulty or not at all. The potato yellow-dwarf virus, readily transmitted by the clover leaf hopper, *Aceratagallia sanguinolenta*, could not be transferred mechanically from clover to clover, although clover is susceptible. Mechanical transmission from potato to potato is difficult, the best method tested giving only 50 per cent infection. In *Nicotiana rustica*, however, mechanical transmission is readily obtained. Rubbing nondiluted juice from diseased *N. rustica* plants over leaves dusted with carborundum may result in the production of as many as 3000 yellow primary lesions per leaf. The primary lesions were employed in making quantitative determinations in studies on the properties of the virus. The virus passes through a Berkefeld W filter, has a dilution end-point of 1×10^{-3},

resists aging *in vitro* for 3 to 4 hours, and is inactivated by heating for 10 minutes at about 50° C. Attempts to recover the virus from dried leaves have failed.

A Sugar-beet Root Rot Caused by Aphanomyces cochlioides. W. F. BUCHHOLTZ and C. H. MEREDITH. In August, 1937, 61 per cent of a random sample of sugar-beet tap roots from Kanawha field were or had been rotted. Brownish discoloration and a water soaked, slightly softened consistency characterized the lesions. Many rotted tap roots had become desiccated and shrunken until only a fibrous tassel-like structure remained. Such plants experienced increasingly severe wilting and eventual death, although the latter was sometimes delayed by an excessive number of short slender side roots. Isolations on August 21 and 23 yielded 2 and 6 cultures of *Aphanomyces*, and on August 31 and September 21 *Aphanomyces* was recovered in 11 of 12 and 23 of 24 trials. Bacterial contaminants were common. Two plug-inoculation experiments in the field yielded 100 and 91 per cent rotted beets. A similar experiment with harvested beets yielded 91 per cent. Symptoms were different from those produced by *Phytophthora drechsleri* inoculations. *Aphanomyces* was reisolated in each experiment. Checks were not rotted. In typical cultures, zoospores emerged as delimited protoplasts from unbranched hyphae and were motile in 12 hours. Oogonia with branched enveloping antheridia were present in 2-day-old cultures. Modal size was 24 μ, range 24 μ to 29 μ. The cultures studied have been assigned to the species, *Aphanomyces cochlioides*.

Pythium de baryanum and Other Pythium Species Cause Alfalfa Seedling Damping Off. W. F. BUCHHOLTZ and CLIFFORD H. MEREDITH. Cultures of 5 species of Pythium, *P. de baryanum, P. splendens, P. pulchrum, P. rostratum* and *P. ultimum*, have been isolated from field-grown, damped-off alfalfa seedlings and shown to be pathogenic under greenhouse and laboratory conditions. In 50 isolation trials with alfalfa seedlings from early 1937 plantings, 43 yielded *P. de baryanum*. In later trials, 53 of 68 isolates were *P. de baryanum*. This pathogen, as in 1935 and 1936, was the one most commonly isolated. April or early may, 1937, plantings of alfalfa and other legumes and sugar beets in 8 fields in southern, central, and northern Iowa yielded uniformly good emergence and survival stands much superior to those from later May plantings. In general, late-planted stands of red clover and sweet clover were superior and late-planted stands of sugar beets were relatively inferior to late-planted alfalfa stands.

Control of Internal Cork of Apple with Boron. A. B. BURRELL. In a 27-year Fameuse orchard, boron treatments on alternate trees reduced internal cork as follows:

(a) Injection of dry boric acid, from 36.45 per cent of the apples (average of 27 check trees) to 0.22 per cent (average of 27 treated);
(b) 1-pound borax on soil, from 13.40 per cent (average 15 checks) to 0.06 per cent (average 16 treated);
(c) ½-pound borax on soil, from 24.99 per cent (average 25 checks) to 0.10 per cent (average 24 treated); all based on slicing 200 fruits per tree.

Limited data on McIntosh and Cortland in 3 other orchards are corroborative. Each injection killed a small strip of bark, but foliage appeared unharmed. No injury is apparent yet from spring (1937) soil application of borax to about 15,000 trees. Thirty-six young trees received liberal soil applications of boron August 13, 1936. In 1937, on 6 of these certain leaves each developed a sizeable white area at the proximal end extending along midrib and main veins. An identical pattern resulted from dipping growing shoots in boron solutions. Two pounds of borax per 100 gallons of common spray mixtures caused mild marginal scorching on immature leaves unless either lime or lime sulphur was present; mature leaves appeared uninjured. Boron seemed ineffective against bitter pit.

Fungi Associated with Oak Diseases. J. C. CARTER. A survey of little-studied oak diseases, initiated in Illinois in 1934, is still in progress. Branch and twig cankers, dieback, twig blight, deep wood infections, and staghead have received special attention on *Quercus alba, Q. bicolor, Q. borealis maxima, Q. ellipsoidalis, Q. imbricaria, Q. macrocarpa, Q. marilandica, Q. muhlenbergii, Q. palustris, Q. stellata*, and *Q. velutina*. Of 137 cankers examined, 71 (group one) bore fruiting bodies of fungi obviously associated as causes of the cankers, while 66 (group two) gave no outward evidence of cause. Microscopic examination of group one revealed species of *Bulgaria, Coryneum, Cytospora, Diatrype, Phoma, Phomachora, Rhodosticta, Sphaeropsis*, and *Ustulina;* and cultures gave species of *Alternaria, Aspergillus, Chaetomium, Coryneum, Cytospora, Fusarium, Penicillium, Phoma, Phomachora, Phomopsis, Rhodosticta*, and *Ustulina*. Cultures of group two gave species of *Alternaria, Coryneum, Fusarium, Penicillium, Phoma, Phomachora, Phomopsis*, and *Ustullina*. From 51 cases of dieback, twig blight, deep wood infections, and staghead, cultures gave species of *Alternaria, Armillaria, Coryneum, Cytospora, Fusarium, Penicillium, Phoma, Phomachora, Phomopsis*, and *Ustulina*. From wood discolorations extending

backward into otherwise healthy wood, only *Phomachora* and *Cytospora* were secured in cultures. The fungus most frequently found associated with staghead and sudden dying was *Armillaria mellea.*

Basicop as a Cherry Spray. DONALD CATION and COLIN W. ROBERTSON.

Cherry-spraying Experiments in Michigan, 1937. DONALD CATION and E. J. RASMUSSEN. Experiments conducted at Hart and East Lansing, Michigan, comparing certain spray materials for the control of cherry leaf spot (*Coccomyces hiemalis*) included lime sulphur, Bordeaux, Basicop, Bordow, copper oxychloride (3 brands), Copper-Hydro 40, 66A, 66B, Z-O, Oxo Bordeaux, copper phosphate, Coposil, and basic copper chloride. A preblossom infection together with well-distributed rain periods were favorable for heavy defoliation due to leaf spot. Lime-sulphur generally failed to control the disease, while most of the copper materials gave adequate protection. These materials were evaluated on the basis of control, injury to the foliage, and resulting size of fruit.

The Occurrence of Lysis in Certain Crosses of Ustilago zeae. ST. JOHN P. CHILTON. Chlamydospores resulting from crosses between certain haploid lines of *Ustilago zeae* germinated abnormally and the promycelia disintegrated. Not all of the promycelia produced by chlamydospores from any one cross disintegrated, but normal promycelia with 4 sporidia were found very infrequently. This lysis appeared in all crosses in which the lethal factor or factors involved were present in one of the parent lines and absent in the other. These lines are the progeny of a single original cross, and the abnormality has persisted through 3 chlamydospore generations. The same original cross has produced haploid lines also, which have remained normal through five chlamydospore generations. When grown in culture, haploid lines resulting from crosses containing the lethal factor or factors were less vigorous than the lines resulting from crosses in which this abnormality did not appear. Abnormal meiotic divisions may occur, as solopathogenic lines were obtained, which, with one exception, arose from crosses involving the lethal factor or factors.

Root Rot of Pines Caused by Armillaria mellea. CLYDE M. CHRISTENSEN. Several hundred jack pine, *Pinus banksiana,* Norway pine, *P. resinosa,* and northern white pine, *P. strobus,* growing in natural forests, were selected at random, dug up, and the roots examined for infection by *A. mellea.* The infection varied from 0.0 per cent on jack pine 5–10 years old to 100 per cent on Norway pine 250–300 years old. Infection was more common in dense stands than in open stands. Suppressed, weakened, or injured trees in dense stands did not appear to be more susceptible to infection than dominant, vigorous, uninjured trees in the same stands. The damage appeared to be greatest in stands under 30 years and over 200 years of age. Rhizomorphs, apparently of *A. mellea,* were present on the roots of practically every woody plant that was dug up, indicating that the fungus probably is generally distributed in the forest. Numerous cultural strains of the fungus were isolated, but none of them was found to attack seedlings of pine and spruce grown in pure culture. The dying of old, over-mature Norway and northern white pines was attributed chiefly to root rot and drouth.

Mosaic Resistance in Nicotiana tabacum. E. E. CLAYTON, H. H. SMITH, and H. H. FOSTER. Seed collections from Mexico, Central America, and South America were tested for resistance to common tobacco mosaic. Thirty-six out of 897 proved resistant, and all resistant lots came from Colombia, South America. Included, were a number of varieties quite distinct from Ambalema. Resistant collections fell into 2 groups: the highly resistant showing none to abundant localized light green spots, and the moderately resistant showing mild systemic mottling. The resistance reaction of the first group, which includes Ambalema, was conditioned by 2 major recessive factors, with indications that this resistance may be affected to some degree by modifying factors.

Fusarium Wilt and Stunt of Spinach in Virginia. HAROLD T. COOK and T. J. NUGENT. A Fusarium wilt of spinach, observed in Virginia for the last 7 years, is becoming increasingly important. It now causes an annual loss of about 3 per cent of the crop, and the loss in some fields is as high as 90 per cent. It is most destructive to spinach planted in late August and in September and to spinach grown for seed. Wilting does not occur until the plants are about 3 weeks old and may not take place until even later. Symptoms of the disease in the young plants are dull green, limp foliage followed by wilting, destruction of the fibrous roots, black lesions on the tap root, and a brown discoloration of the stele. Symptoms in the older plants are stunting, yellowing and wilting of the outer leaves, a reduced root system, and brown discoloration of the stele. Cool weather retards the disease, and plants in which infection has not progressed too far often form new roots and make a good growth late in the fall. The fungus that causes stunt and wilt does not decay the seeds or cause damping off; seed treatment is ineffective as a control measure.

Experiments in Crossing Varieties of Puccinia graminis. RALPH U. COTTER and MOSES N. LEVINE. Pycnial nectar of *Puccinia graminis agrostidis* was mixed in various combinations with that of *P. graminis tritici, P. graminis secalis, P. graminis poae,* and *P. graminis avenae,* respectively. While aecia resulted from less than 35 per cent of 382 crosses attempted, some were produced from every combination, although no uredial cultures were obtained from *agrostidis* × *avenae* or its reciprocal. Positive results include: 16 *tritici* and 2 *hordei* races from *tritici* × *agrostidis*; 5 *tritici*, 2 *hordei*, and 1 *secalis* from *agrostidis* × *tritici*; 9 *tritici*, 4 *secalis*, and 1 *avenae* from *secalis* × *agrostidis*; 4 *tritici* and 1 *secalis* from *agrostidis* × *secalis*; 3 *tritici* races from *poae* × *agrostidis*. A few *tritici* and *secalis* races isolated attacked many of their respective differential hosts. Some isolates were common races but several strains were new. The one *avenae* strain isolated was race 5, and three of the *hordei* races were new. While none of the *hordei* races could succesfully attack any other grain besides barley, they differed in parasitism on three varieties of barley. Finally, a strain was isolated from a cross of *P. graminis tritici 17* × *P. graminis agrostidis* producing fairly severe infection on Gopher oats in addition to attacking normally different varieties of barley. (Division of Cereal Crops and Diseases, Bureau of Plant Industry, and Division of Plant Disease Control, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, in cooperation with the Minnesota Agricultural Experiment Station.)

Inhibitory Substances Generated by Gibberella saubinetii. G. N. DAVIS. An inhibitor was produced in 14 days by *Gibberella saubinetii* in Czapek's liquid media in which ammonium tartrate was used as a source of nitrogen. The filtrate was removed from the flasks and added in various dilutions to hard Czapek agar. The growth of *G. saubinetii* at 15° C., on agar plates containing 50 per cent or more of the filtrate reduced to 50 per cent of that made by the check. On other plates, containing 30 per cent of the filtrate, the growth was 75 per cent. When talc was added to the filtrate (1 gm. per 100 cc.) as an adsorbent and stirred vigorously for 20 minutes, approximately 80 per cent of the inhibitor was removed from the filtrate. The inhibitor retarded *Gibberella* in infected seeds. Infected seed, soaked for 24 hours in the inhibitor, gave a 59 per cent germination at 10° C. Seed from the same lot, treated with ethyl mercury phosphate, showed 57 per cent germination, and the checks 46 per cent.

Smut in Latent Buds of Sorghum. G. N. DAVIS. When the terminal panicles of the sorghum plant are removed the latent axillary buds become active, producing new panicles. *Spacelotheca sorghi* may infect many of the growing points in the terminal shoot, as already shown by the writer for *Ustilago zeae* of maize. This is apparent from the following experiments. Four orange cane plants, naturally infected with *Spacelotheca sorghi,* planted on May 14, 1935, are actively growing in the greenhouse and continue to produce smut-infected panicles. During these 2½ years, 122 smutted panicles have developed on 4 plants. Six plants of a similar series, 1½ years old, have yielded 78 smutted panicles and 14 healthy ones. The check plants never produced a single infected panicle. Plants inoculated by the hypodermic-needle method when about 30 days old, yielded 14 smutted and 11 healthy panicles. Smut in the plants hypodermically inoculated developed only in panicles from axillary buds on inoculated culms. Noninoculated culms produced smut-free panicles.

The Black-seed Disease of Strawberry. J. B. DEMAREE and MARGUERITE S. WILCOX. An occasionally important minor disease of strawberry fruits, caused by the leaf-spot fungus, *Mycosphaerella fragariae,* has been observed in Maryland and North Carolina. The designation "black-seed" has come into general use by growers, owing to the black color of affected achenes and the epidermis of the receptacle immediately surrounding their attachment. The blackened achenes are quite conspicuous on the white unripe fruits, and on ripe fruits of light-colored varieties. Usually, only 1 or 2 spots occur on affected berries, but, occasionally, as many as 8 or 10 spots are found. It is believed that infection enters by way of the stigma, and the fungus ramifies throughout the seed structure and closely associated pulpy tissues. A fungus has been isolated from the infected pulp and achenes resembling morphologically and culturally the conidial stage of *M. fragariae.* The black-seed disease was produced in the greenhouse by inoculating young berries with cultures of the fungus isolated from the infected berry tissue, from strawberry leaf-spot lesions, and from ascospores of *M. fragariae.* Typical lesions of strawberry leaf spot also were produced by inoculating young strawberry leaves with the isolate made from the black-seed-affected berry tissues.

A Simplified Technique for Tobacco-virus Purification and Crystallization. B. M. DUGGAR and WAYNE E. MOORE.

A Survey of the Fungi Associated with Wood Decay in Apple Trees. CARL J. EIDE and CLYDE M. CHRISTENSEN. Sixty-eight apple trees, 22 years old and well cared for,

were sawed off about 3 feet above ground and again at ground level. Of these, 12 were badly decayed, 22 moderately so, 22 slightly rotted, while in 12 there was no visible sign of decay. Fruiting bodies of *Daedalia unicolor* were found on one of the badly decayed trees and *Polyporus versicolor* on another. In another orchard, neglected for over 10 years, fruiting bodies of the following fungi were found on decaying trees: *Fomes applanatus, Trametes hispida, T. malicola, Pholiota adiposa, Polyporus versicolor,* and *Thelephora* spp. Cultures were made from the fruiting bodies and from decayed wood, and it seems probable that these fungi are responsible for active decay in living trees. Several other Basidiomycetes were isolated from decaying apple wood, one of which has been identified provisionally as *Polyporus resinosus.* Fruiting bodies of the following fungi were observed on dead branches of apple trees: *Polyporus tulipiferas, P. pubescens, P. versicolor, Lenzites trabea,* and *Daedalia unicolor. Schizophyllum commune* is abundant on sun-scald cankers and other dead bark. It was isolated from dead bark but never from decayed wood.

Buckwheat as a Factor in the Root Rot of Conifers. E. J. ELIASON. A severe root rot appeared during a warm period in a block of red-pine transplants, in June, 1933, at the Saratoga Nursery of the New York State Conservation Department. It was noted that the rot was found in parts of the nursery, successively sown for three or more years with buckwheat as a cover crop. Field and laboratory studies have shown definitely the relation of the buckwheat residue to the rot. The fungus appears to be one or more species of *Fusarium.* High temperatures increase the severity of the rot. Tests of susceptibility have shown red pine to be the least resistant. Norway spruce proved to be almost immune, while white spruce and white pine are intermediate. Transplants suffer the greater loss during the first year. Infected soils also cause damping off and root rot to one-year seedlings in the seedbeds. Control by means of soil treatment has met with little success. Areas on which no additional buckwheat or other organic materials have been added, still produce severe rot after 4 years. Practical control has consisted of the planting of susceptible species on noninfected areas and early planting to avoid higher soil temperatures of late spring.

Root Infection of Allium Species by Urocystis cepulae. E. L. FELIX. Mature smut lesions resembling those on the cotyledons and true leaves occurred occasionally in the field and greenhouse on primary and secondary roots of 4- to 6-week-old seedlings belonging to *Allium cepa, A. fistulosum,* and *A. porrum.* Infected areas, which varied from 1/32 to over an inch in length, ranged from brown to black, depending on the number and maturity of spores. Invasion of both primary and secondary roots seemed invariably to originate from infections in the region of the root joint, either of the sheath itself or of the meristematic "plate." The sheath normally surrounds the forming secondary roots, which stretch and ultimately rupture it, leaving a temporary collar at the base of the root or carrying a sleeve-like portion of it anywhere on the root. Smut hyphae are intercellular in the roots, as in the cotyledon. Mycelium and spores occurred infrequently in the root hairs.

The Isolation and Identification of the Pigment Present in Cultures of Actinomyces violaceus-ruber. VERNON L. FRAMPTON and C. F. TAYLOR. The pigment elaborated by *Actinomyces violaceus-ruber* has been identified as an anthocyanin, and has been isolated as the crystalline picrate. The pigment is a rhamnose glucoside, the carbohydrate groups being rhamnose and glucose. Solubility studies suggest that the sugars are separately attached to the anthocyanidin residue. The anthocyanidin remains to be identified.

Physiological Variation in Isolates of Polyporus schweinitzii. WM. D. GRAY. Weighed wood blocks of white-pine sapwood were inoculated with ten different isolates of *Polyporus schweinitzii,* obtained from various localities and various coniferous hosts. Cultures were maintained for 10 months; the blocks were then air-dried, weighed, and percentage weight losses were obtained for each series. Statistical analysis of results reveals that striking differences in wood-decaying ability exist between various isolates of this species.

Alkaloids Isolated from Plants Resistant to Phymatotrichum omnivorum and Their Influence on Growth of the Fungus. GLENN A. GREATHOUSE. Preliminary studies indicated the presence of alkaloids in crude extracts from roots of several plants resistant to *P. omnivorum.* Six alkaloids have been isolated in pure form from these extracts, and their influence on growth of the organism determined. Only the nitrogen content and the physical properties of these compounds have yet been determined. Similar extracts from roots of several susceptible plants did not yield crystalline alkaloids. The toxicity of the crude extracts on the growth of *P. omnivorum* in certain instances was greater than

the toxic effect that could be ascribed to the amount of alkaloids isolated from a given unit of extract. This indicates that the quantity of alkaloids isolated either represents only a fraction of the total present or suggests that still other entities may be responsible for a portion of the toxicity to the organism. A search is being made for other possible chemical entities that may be responsible for a portion of the resistance to the fungus. In addition to the alkaloids isolated, 27 other alkaloids from resistant and susceptible plants have been obtained through several investigators and their effect on the organism recorded.

Parasitism and Physiologic Specialization in Fomes lignosus. EARLE W. HANSON. A Liberian culture of *Fomes lignosus* caused severe infection on *Hevea brasiliensis* and *Ficus elastica* in artificially inoculated soil. Typical symptoms of the white-root disease appeared 5 weeks after inoculation, and in approximately 6 weeks the plants were dead. Checks remained healthy. The pathogen was reisolated from the roots of dying plants and found to be identical in all respects with the original culture. Histological studies showed that the fungus was abundantly present in the diseased roots. Similar investigations with a number of leguminous crops showed that navy beans, soybeans, cowpeas, and garden peas also are susceptible to *F. lignosus.* A culture of the fungus obtained from Malaya was compared with the Liberian isolate and found distinctly different in cultural characters, rate of growth, temperature and moisture requirements, and in pathogenicity. On most media the Malayan culture produces a finer, faster growing mycelium than does the Liberian isolate. It has an optimum temperature of 32° C. as compared with 27° C. for the latter. Its moisture requirements for optimum growth are greater than for the Liberian, which grows best under conditions of relatively low moisture. The Liberian isolate is much more pathogenic on legumes than is the culture obtained from Malaya. (Minn. Agr. Exp. Sta. and Firestone Plantations Company, cooperating.)

Preliminary Studies on the Cytology of Urocystis waldsteiniae. E. W. HANSON and R. E. ATKINSON. In *Urocystis waldsteiniae* the haplophase apparently has been almost eliminated. The fusion nucleus apparently undergoes meiosis in the chlamydospore, as very young promycelia are binucleate and all subsequent vegetative development is dikaryotic. Individual cells of septate promycelia, and sporidia, are almost invariably binucleate. The mycelium in the host is usually multinucleate, at first, but becomes binucleate with the formation of septa. Even in nonseptate hyphae, the nuclei are commonly associated in pairs. Chlamydospores are binucleate until almost fully developed, when, following fusion, they become uninucleate. Chlamydospores of *U. waldsteiniae* require no rest period. They germinate readily in water within 48 hours, normally producing a single promycelium, but occasionally more. Sporidia, germ tubes, or both, usually 2 in number, are produced by the young promycelium, either laterally or 1 laterally and 1 terminally. Sporidia are very large and readily abstricted. They have never been observed to bud, but germinate from one or both ends, or occasionally from the side. Promycelia, likewise, may become detached from the spore and behave like sporidia.

Blue Rot of Boxwood. J. G. HARRAR. Isolations from over 300 diseased boxwood plants from various parts of Virginia indicate that *Verticillium* species are invariably associated with the so-called blue rot of *Buxus.* On the basis of morphological and cultural characters, 9 apparently distinct strains of *Verticillium* have been isolated from the diseased plants. Infection of healthy boxwoods has been obtained with 3 of these strains. From experimental evidence, it seems probable that the organisms involved are only weakly parasitic and that predisposition is essential to infection.

Phoma (Phyllosticta) antirrhini in Virginia. J. G. HARRAR and L. I. MILLER. The Phoma disease of snapdragons has been wide-spread in Virginia during the past three years. The causal organism has been identified as a species of *Phoma,* probably identical with the organism previously reported as *Phoma* and also as *Phyllostica antirrhini.* Moreover, since other members of the Scrophulariaceae have been successfully infected with this fungus, it may possibly be identical with other species reported on these host plants. As recorded earlier, *P. antirrhini* causes damping off of young plants and produces stem cankers and leaf spots on older hosts. In addition, it has been found to produce severe seed-pod infection. In the field, maximum injury occurs on older plants. It has been demonstrated that the disease is both soil- and seed-borne, and experimental results indicate that seed selection, seed treatment, and sprays offer practical control measures.

Microchemical Studies of Potato Tubers Affected with "Blue Stem." L. M. HILL and C. R. ORTON. A technical description of this disease appeared in Jour. Agr. Res. 55: 153–157. 1937. Tests for cellulose showed this compound to be absent or frag-

mentary in the cell walls of the necrotic areas of parenchyma and phloem, while tests for cellulose and lignin were positive in the walls of necrotic xylem. Pectin was present in healthy but absent in diseased tissues. Suberin was detected in the necrotic parenchyma, phloem, and xylem. Protein seemed to be absent within diseased regions. Fat was found uniformly distributed throughout diseased and healthy tubers, although the yellow precipitate, associated with necrotic regions, gave a negative fat test. Glucose was detected in healthy and diseased tubers, but with greater concentration in the necrotic regions. Sucrose was found in very small quantities in both healthy and diseased tubers; the same applied equally well to potassium, phosphates, magnesium, calcium, and sulphates. Iron was concentrated around diseased areas. No nitrates were found in the necrotic areas and adjoining cells. Oxidase was concentrated in a zone surrounding the necrotic regions.

Pythium graminicolum on Barley in Iowa. WEN-CHUN HO and I. E. MELHUS. In May, 1936, it was observed that the stand of barley was unusually thin in many fields in central Iowa and that the plants were yellow and stunted. Some were flaccid and dying; at heading time the height of the grain was very uneven. The stunted plants headed short and were conspicuously yellow in contrast to the dark green healthy plants. A species of *Pythium* was isolated from the infected roots, which was identified as *P. graminicolum* and shown to be the causal agent of the disease. Cross inoculation indicated that timothy, millet, wheat, rye, and maize were actively parasitized, while oats and sorghum were much more resistant. *P. graminicolum* grew better in steamed alkaline soil than in acid soil (range of pH 4 to 11). The hyphae penetrated the root tips in the zone just back of the cap, moving inter- and intracellularly. Sex organs developed profusely in the parenchymatous tissue and vascular bundles of the young infected roots. Marked root necrosis and stunting of the aerial parts developed on seedlings grown in association with the pathogen in glass cylinders partially filled with steamed soil.

Strains of Tobacco Resistant to Tobacco Mosaic. FRANCIS O. HOLMES. A dominant gene, inducing a necrotic type of response to infection with tobacco-mosaic virus, has been transferred from *Nicotiana glutinosa* to *N. tabacum* through the intermediacy of the amphidiploid species *N. digluta*. After hybridization, successive backcrosses to *N. tabacum* combined with the selection of necrotic-type individuals produced *tabacum*-like plants which, when infected, had the disease manifestations characteristic of *N. glutinosa*. Repeated self-pollinations gave rise to wholly necrotic-type strains of tobacco. In the presence of the gene conferring the necrotic type of response, transfer of virus from infected plants is difficult. It is believed that tobacco-mosaic virus will be unable to maintain itself in the field in tobacco plants bearing this gene.

The Lime Factor in Bordeaux Injury. JAMES G. HORSFALL and R. F. SUIT. It was early established that copper in Bordeaux injures plants. The injury was lessened, never quite eliminated, but sometimes accentuated by increasing the lime. The accentuation was due to the lime itself on such lime-sensitive plants as the Solanaceae, Cucurbitaceae, hops, ginseng, roses, and others. Correct reply to the following questions will enable one to determine lime injury: Does lime alone produce it? Does reduced lime reduce it? Do "insoluble" coppers, minus lime, produce it? Lime damage is easily reproducible in the greenhouse, copper injury is not. Damage is favored by high temperatures on spray date; sprays are more injurious than dusts. Damage is reduced by lime carbonation or by antagonism of magnesium. Lime injury shows externally as a leaf deformation and accelerated transpiration; internally, as stunting and crisping of plant organs. The surface effects apparently result from a dissolution of cuticle, soluble in warm alkalis. Excess lime-Bordeaux or lime applied in water on a hot day furnishes ideal conditions for dissolution of cuticle, penetration of calcium, and increased water loss. Carbonation of the lime, or reduction in the concentration, would reduce the alkalinity and, simultaneously, the injury. Stunting and crisping aspects of lime damage probably result from a hardening of the cell walls by the calcium, so that they do not expand normally.

Soil Sterilization by Chloropicrin for Field Crops and Vegetables. FRANK L. HOWARD.

Effect of Growth-Inhibiting Suubstances Present in Nutrient Solutions of Aspergillus Species. WM. G. HOYMAN. Four species of *Aspergillus* were grown on Czapek's solution at room temperature for 15 weeks. The solutions were then filtered and autoclaved. The growth of each species was measured on potato-dextrose agar containing 10 ml. of filtrate. The toxic substance obtained from *Aspergillus niger* did not inhibit its own growth but reduced that of *A. terreus* approximately 90 per cent, *A. ochraceous* 40 per cent, and *A. wentii* 50 per cent. *A. ochraceous* did not produce a substance inhibiting the growth of the three other species, but its own growth was about 70 per cent that of the check. The filtrate of *A. terreus* inhibited the growth of that species, as well as that of *A. wentii* and

A. niger, approximately 50 per cent. That of *A. ochraceous* was retarded about 60 per cent. The filtrate of *A. wentii* checked the growth of *A. terreus* for 7 days, while the growth of *A. ochraceous* was 40 per cent that of the check. No effect was evident on the growth of *A. niger*, but its own growth was retarded about 40 per cent. It is evident that a thermostable growth-inhibiting substance is present in the filtrate of each species and is nonspecific in 3 instances.

Relation of Upper-air-mass Movement to Incidence of Stem Rust. H. B. HUMPHREY. An analysis of any major epidemic of stem rust and an interpretation of the rôle of weather in inducing it require consideration of high-elevation winds. Examination of weather data for the period May 15 to June 30, 1935, shows that at 4,000 ± feet the air-mass movement was often westward to southward to Oklahoma and Texas and thence sometimes northward. Such winds, carrying spores from New York, Pennsylvania, and the Great Lakes States, may have transported initial inoculum into Texas, Oklahoma, and Kansas. Weather data for May 1 to June 30, 1937, show a north-to-south high-elevation (4,000 ±) wind movement for a total of 18 days and of 43 days from south to north. On 29 out of 43 days the winds moved northward to Kansas, thence across Missouri and eastward. This preliminary study suggests the probable importance of the barberry in the North-Northeastern States to incidence of rust in the Midwestern States. To make a more comprehensive analysis of upper-air movement and its importance in transporting rust inoculum, it is proposed to release at stated times and places enough cornstarch to indicate the course of such winds and the ultimate disposition of their spore and dust content, caught by spore traps.

The Effect of Several Sulphur Sprays on the Photosynthesis of Apple Leaves in a Controlled Environment. RUSSELL A. HYRE. These studies were made on McIntosh and Baldwin apple leaves at temperatures of 70°, 85°, and 100° F., relative humidity of 60 per cent, and with the light provided by a unit of 4 10,000-lumen sodium vapor lamps. During 32½-hour periods (after spraying *vs.* before spraying) lime-sulphur solution, 2–100, gave about twice the reduction in photosynthesis as did Magnetic Spray Wettable Sulphur and Micronized Wettable Sulfur, both at 6 lbs. per 100 gallons. The reduction was about the same at 70° and at 85° but increased markedly at 100°. (At 85° the approximate reductions were: lime sulphur, 18½ per cent; Magnetic Spray Wettable Sulphur, 7½ per cent; Micronized Wettable Sulfur, 7½ per cent, while the check increased 3½ per cent. At 100° the reductions were about 59, 34½, 34½ and 12½ per cent, respectively.) During a 26-hour period, at 85° F., lime-sulphur solution, 2½–100, with and without arsenate of lead at 3 lbs. per 100 gallons, gave essentially the same reduction, whether applied to both surfaces of the leaf or to the lower surface only. When applied to the upper surface only, the reduction was slight. It seems probable that the marked increased in injury from lime sulphur on apple foliage, noted in recent years, may be due to the change in method of application; *i.e.*, from overhead applications with nozzles on spray rods to heavy driving applications from the ground with spray guns.

Further Determinations of the Carbohydrate-nitrogen, Relationship and Carotene in Leaf-hopper-yellow and Green Alfalfa. H. W. JOHNSON. Leaf-hopper-yellow alfalfa leaves, whether from infested cages or non-dusted plots, are higher in dry matter, reducing sugar, total sugar, and total acid-hydrolyzable substances, but are lower in total nitrogen than are green alfalfa leaves from noninfested cages or dusted plots. On the other hand, stems of leaf-hopper-yellow alfalfa plants from non-dusted plots are lower in dry matter, reducing sugar, total sugar, and total acid-hydrolyzable substances, but are higher in total nitrogen than are stems of green plants from dusted plots. The congestion of carbohydrates in the leaves and the deficiency of these substances in the stems of alfalfa plants yellowed by the potato leaf hopper, *Empoasca fabae*, are considered further evidence that the injury caused by this insect is due to a clogging of the food-conducting elements, with resultant interference with the translocation of elaborated food in the infested plants. In 1937, leaf-hopper-yellow, second-cutting Grimm alfalfa (leaves and stems) from an uncaged area contained only 71 milligrams of carotene per kilogram of dry matter, whereas green alfalfa from a caked area in the same small plot contained 227 milligrams per kilogram. The yellowed alfalfa is, therefore, only about one-third as rich in potential vitamin A activity.

Crotalaria Mosaic. H. W. JOHNSON and C. L. LEFEBVRE. A disease characterized by a general stunting of the plants, by mottling, blistering, and malformation of the leaves, and by abnormally stimulated lateral branching or witch's brooming was prevalent in the Crotalaria nursery at Arlington Experiment Farm, Arlington, Virginia, in 1937. The percentage of diseased plants in one or two rod rows of the *Crotalaria* species present was as follows: *striata* 86.7, *usaramoensis* 76.2, *intermedia* 71.6, *maxillaris* 58.1, *incana* 57.3, *spectabilis* (early strain), 46.2, *spectabilis* (late strain) 33.3, *lanceolata* 31.8, and *retusa*

0.00. From 50 to 67 per cent positive transmission of the virus from *C. spectabilis* and *C. usaramoensis* to healthy *Vicia faba* plants was obtained by rubbing the leaves with cheesecloth soaked in extract from mosaic plants, using white quartz sand as an abrasive. Definite mosaic symptoms were evident in 14 days. Eight noninoculated plants remained healthy. Witch's broom or curly disease of *C. anagyroides* and *C. juncea* was reported from Java in 1927 by M. B. Schwarz, who suggested that this might be a virosis spread by insects. The present report is thought to be the first record of the occurrence of this disease in the United States.

Brown Root Rot of Tobacco. JAMES JOHNSON. The true nature of brown root rot has remained obscure for 20 years. Fortunately, the disease may be prevented in field practice by avoiding certain preceding crops. No parasite has been conclusively and regularly associated with the disease. Histological studies reveal no organism in the diseased tissues. Diseased cells are brown and sharply delimited from normal cells. The cell walls are thickened and the cell contents granular before complete disintegration. The lesions are generally limited to the cortex, lateral progress of the disease being effectively checked in the endodermal region. Studies on the properties of the causal agent have shown that it is destroyed by drying. Temperatures of 45° C. for one day, freezing below – 10° C. for several days, charcoal and many chemical disinfectants also eliminate the causal agent from the soil. Air, pure oxygen, or light has little or no effect. Diseased root pulp reproduces the disease, but filtered extracts of diseased roots or water extracts of the soil do not. The possible relation of toxins produced by soil saprophytes is being investigated further, but no conclusion has been reached as to the true nature of the causal agent.

Crinkle and Mosaic of Geranium. LEON K. JONES. Two viroses of geranium, *Pelargonium zonale*, observed in greenhouses in the State of Washington, have been designated as crinkle and mosaic. Both viruses are transmissible to geranium by grafting but nontransmissible to geranium, tobacco, and tomato by mechanical inoculation. Crinkle is characterized by development of irregular to circular, chlorotic areas, one-half to 2 mm. in diameter, in the leaf tissue; ruffling, dwarfing, yellowing and dropping of foliage; dwarfing of plants during the midwinter months; and masking of symptoms during the summer months. Mosaic is characterized by mottling of foliage with light and dark green areas, dwarfing of leaves, and shortening of stem internodes. The light green areas are usually large, irregular, and interveinal.

The Resistance of Katahdin Potato Seedlings to Infection by the Veinbanding Virus and the Tobacco Mosaic Virus. LEON K. JONES and EARL F. BURK. Tests in the greenhouse with seedlings produced from an Early Northern × McCormick cross (200–5) and from Katahdin selfed have shown that the Katahdin selfed seedlings carried considerable resistance to infection by the veinbanding virus, but the 200–5 seedlings were very susceptible; and that the symptoms in the affected Katahdin selfed seedlings varied from mottling to severe necrosis, but the symptoms in each of the affected 200–5 seedlings were characterized by mottling without necrosis. Similar results were observed from natural infection in the field, except that percentage of infection was higher than that obtained by mechanical inoculation in the greenhouse. Seedlings produced from a 200–5 × Katahdin cross showed a lesser degree of resistance to natural infection by the veinbanding virus that the Katahdin selfed seedlings but a slightly greater tendency towards necrosis in affected plants. Mechanical inoculation with common tobacco mosaic (tobacco virus 1) into Katahdin selfed and 200–5 seedlings in the greenhouse showed that Katahdin selfed seedlings were immune from and 200–5 seedlings were somewhat susceptible (8.3 per cent) to infection; and that symptoms in affected 200–5 seedlings varied from severe necrosis to mottling without necrosis.

The Value of Some New Copper Fungicides for Apple Blotch (Phylloticta solitaria) Control. K. J. KADOW and H. W. ANDERSON. All the new fungicides intended as substitutes for Bordeaux mixture, which could be secured readily, were tested in an experimental way as possible apple-blotch sprays. With few exceptions, the materials were used as recommended. Those tested were Bordeaux mixture, Bordeaux 34 with zinc sulphate and lime, Oxo Bordeaux, Basicop, Coposil, Copper Zeolite, copper phosphate with lime and bentonite, Cupro K, Cuprocide 54, 66a, Copper-Hydro 40, and a special copper from the Niagara Sprayer and Chemical Company. The sprays were applied to specially selected Duchess trees, and the season was ideal at Urbana, Illinois, for the development of blotch and spray injury. Of all materials used, the only ones that controlled blotch and, at the same time, did not cause commercially important spray injury were (concentrations in 100 gallons of water): Bordeaux 34 (2 pounds) with zinc sulphate (¾ pound) and lime (¾ pound); Oxo Bordeaux (6 pounds), Copper Zeolite (3 pounds); Copper-Hydro 40 (3 pounds); and Cupro K (3 pounds). Copper phosphate (4 pounds), used

with 6 or 8 pounds of lime and 4 pounds of bentonite, may also be satisfactory, since, at one-half that strength, the spray controlled all but petiole infections, without spray injury. Cupro K caused slight specking on some fruit.

Heterothallism and Segregation for Pathogenicity in Venturia inaequalis. G. W. KEITT, D. H. PALMITER, and M. H. LANGFORD. In 1936, using cultures and methods previously reported (Science, n.s., 85: 498), 8 monoascosporic isolates from an ascus were inoculated separately and in all possible pairings on apple leaves, which, with controls, were overwintered and examined for perithecia. Seven of the 36 inoculated samples disintegrated. Data from the others, confirming previous results, indicate that the isolates comprise 2 groups of 4 each, being hermaphroditic, self-sterile, intra-group sterile, and inter-group fertile. All 14 available samples from the 16 expectedly fertile pairings, and none other, yielded mature ascocarps. Singly and in all possible pairings the same 8 isolates were cultured on cheesecloth "wicks" in bottles containing nutrient solutions. Perithecial initials were formed in all cases. They grew larger in expectedly fertile pairings than others. Mature ascospores were produced only from the 4 inter-group pairings involving isolate 8. On leaves of differential apple varieties 4 of the 8 isolates were typically pathogenic; 4 induced only flecking. Two isolates of each fertility group comprised, each 4, of like pathogenicity. Inoculation experiments with cultures from ascospores of known serial arrangement in the asci showed that segregation for pathogenicity occurred alternatively in the first or the second nuclear division in the ascus.

A Seed-borne Bacterial Disease of Garden Stocks, Matthiola incana. JAMES B. KENDRICK. A serious bacterial disease of garden stocks has been present in commercial plantings in certain coastal sections of California since 1933. On seedlings the first evidence of the disease is a soft, watersoaked condition of the stem and the collapse of the plant. Older, more woody plants show large, irregular, oblong to linear, watersoaked areas on the stem and branches that later become sunken, dark brown lesions. Complete girdling of the main stem or branches often results in the death of the plant or the affected branches. Isolations and pathogenicity studies have shown that a yellow *Bacterium* is the cause of the disease. The organism closely resembles *B. campestre* in morphologic and cultural characters, but reciprocal cross-inoculations have failed. Seed from diseased plants grown in sterile soil has shown the causal organism to be seed-borne. The organism has been cultured from the seed. Microtome sections also have shown the bacteria in the seed coat and funiculus. Effective control has been secured by hot-water treatment of the seed for 10 minutes at 53° C.

The Inhibiting Substance Formed by Diplodia zeae. G. C. KENT. A cultural study on the nature of the inhibiting action of filtrates of *Diplodia zeae* on the growth of mycelium of this species has been carried out. The inhibitor was obtained after 35 to 42 days' growth on a modified Czapek's solution and withstood dilution with distilled water up to 1–125. The inhibitive action was not destroyed by oxidation, by correction of hydrogen-ion concentration, replacement of sugar in the cultural medium, moderate hydrolysis under acid or alkaline conditions, or by boiling for 1 hour. The alkaline nature, insolubility in ether, and nonvolatile nature of the inhibitive material, coupled with the above data, are believed to indicate the presence of one or more complex nitrogen-containing compounds. This inhibitor has been obtained by extracting various modifications of Czapek's medium, sterilized grain media, and corn plants growing in the field, all of which have supported the growth of the organism.

The Relative Effect of Genetic and Environmental Factors on Growth Types of Ustilago zeae. M. F. KERNKAMP. When sporidia are isolated from many promycelia of *Ustilago zeae*, the resulting cultures are usually sporidial, at first. Some change promptly to mycelial; some remain sporidial for varying periods of time, then become intermediate or mycelial; others remain sporidial indefinitely. As the factors affecting these changes were not known, sporidial, mycelial, and intermediate cultures were grown under varying environmental conditions. It was found that the intermediate lines varied considerably with certain environments, whereas mycelial and sporidial lines remained relatively constant. Chlamydospores resulting from crossing sporidial and mycelial lines gave rise to promycelia on which sporidia and hyphal branches were produced in the following ratios: 4: 0, 3: 1, 2: 2, and 1: 2: 1. When chlamydospores of this cross produced 4 sporidia it was possible to isolate all 4 and grow them in culture. These produced either sporidial or mycelial growth in the same ratios as given above. The results show that the growth types are determined genetically and that the environment influences intermediate lines considerably, although it has no appreciable effect on sporidial or mycelial lines.

Effect of Prolonged Storage of Treated Seed Corn. BENJAMIN KOEHLER. Seed corn was treated with Barbak III, Merko, and Semesan Jr. (Cresol mercury 1929–32, ethyl mercury phosphate 1933–37), so as to give a storage period of 3 months as compared with only 1 day before planting in a 5-year test. In another test, running 4 years, seed was held over for 1 year, some being treated a year before planting and some not until immediately before planting. All tests were made with seed having a moisture content of 12 per cent or less. When storage was in a warm building or in a closed, unheated warehouse, the yields of plants grown from stored treated seed were frequently as good as or better than those from freshly treated seed. There were, however, some cases of seed injury. On the whole, the freshly treated seed gave the better performance by a small margin. When storage of treated seed was up under the roof of an open shed, there was definite injury to the seed in every case. The several mercurials used gave somewhat similar results with respect to the effect of storage on treated seed.

Seed Treatment Tests with Crown-injured Corn. BENJAMIN KOEHLER. During the past 2 years crown-injured seed corn has been included in the routine testing of commercial seed disinfectants at the Illinois Station as an accelerated method of testing the protective properties of disinfectants against soil-borne organisms. Parallel treatments also were made with good seed and Diplodia-infected seed, both with sound seed coats. Yield of grain from crown-injured nontreated seed corn has been from 20 to 35 per cent below that from grain similarly injured, but treated with some of the better disinfectants. Red copper oxide was one of the best disinfectants for protecting the seed against soil-borne infection. It was slightly better than the mercurials, perhaps, through greater safety for the sprouting embryo. In the control of Diplodia seedling disease, however, certain mercurials were in the lead, red copper oxide being only 59 per cent as good as the best of these. Of 2 new proprietary compounds, one gave partial control against soil-borne infection but none against Diplodia, while the other behaved in the opposite manner, giving partial control of Diplodia, but, apparently, because of toxicity, it gave only a decrease in yield when applied to crown-injured seed.

Properties and Host Range of a Cabbage Mosaic Virus. R. H. LARSON and J. C. WALKER. The virus of cabbage mosaic found in southeastern Wisconsin appears to differ from those viruses previously described. Shepherd's purse, *Capsella bursa-pastoris,* and penny cress, *Thlaspi arvense,* were proved to be natural overwintering hosts. *Myzus persicae* and *Brevicoryne brassicae* are vectors. The virus is inactivated at 55° C. for 10 minutes; it remains infectious *in vitro* for 2 days at 20° to 22° C. and when diluted up to 1 to 1000. Systemic infection was obtained on all cultivated and wild species of *Brassica* tested, on dame's violet, *Hesperis matronalis,* and on wallflower, *Cheiranthus allonii.* On stock, *Mathiola incana,* infection was followed by breaking of the flowers and variegation of the petals. Systemic infection also was obtained on spinach, Swiss chard, sugar beet, zinnia, and calendula. Local lesions were produced on *Nicotiana tabacum* (var. Conn. Havana No. 38), *N. calyciflora, N. sylvestris,* and the F_1 hybrid of *N. tabacum* × *N. glutinosa;* local lesions followed by systemic infections occurred on *N. repanda;* systemic infection occurred on *N. bigloweii, N. glutinosa, N. langsdorfii, N. muelivalvis, N. quadrivalvis,* and *N. rustica.*

A Potato Wilt Caused by the Tarnished Plant Bug, Lygus pratensis L. J. G. LEACH and PHARES DECKER. A destructive wilt of potatoes observed in Minnesota since 1935 resembles Fusarium wilt, although the symptoms are not typical. Repeated inoculations in field and greenhouse with Fusaria isolated from diseased plants failed to produce the disease. Field experiments with hill- and tuber-unit plots indicate that the disease is not tuber-transmitted, and the prevalence of the disease on virgin soil planted with selected healthy tubers indicates that it is not soil-transmitted. The disease is not appreciably influenced by fertilization. Tarnished plant bugs were abundant in affected potato fields, and, when nymphs and adults were allowed to feed for approximately 2 weeks on the stems of potato plants in the greenhouse, a characteristic wilt was produced. About 3 weeks after the bugs were removed a marked chlorosis appeared on the terminal leaves, although the bugs fed only on the stems. Only the stems on which the bugs fed were affected. The stems wilted about 10 days after the apparance of the first symptoms on the leaves. The symptoms were not identical with those observed in the field but may be comparable when due allowance is made for the effect of the greenhouse environment. (Cooperative investigations between the Division of Plant Pathology and Entomology, University of Minnesota.)

A Practical Solution of the Sclerotium rolfsii Problem in the Beet-sugar Industry. LYSLE D. LEACH and JAMES B. KENDRICK. *Sclerotium rolfsii,* first observed in 1931, was

then believed to be a serious threat to the beet-sugar industry of central California. The loss in 1933 was about 5,000 tons and the known infested acreage increased from 4,600 in 1932 to 17,600 in 1936. The spread of the fungus has been checked by proper handling of screenings from beet loading stations, wash-water from sugar factories, agricultural machinery, and livestock from infested fields. A method of soil sampling to determine the population of viable sclerotia has been developed. The volume of inoculum in the soil increases rapidly with each crop of beets and decreases in seasons when certain other crops are grown. By proper crop rotation, the soil inoculum may be reduced to the point where beets may safely be grown again within 3 to 5 years. Fields known to be infested are being indexed annually by the soil-sampling method, and the incidence of infection rather accurately predicted. Infection may be distinctly reduced by the application of nitrogenous fertilizers. During 1936 and 1937, there has been a definite decrease in the rate of spread of the fungus and a very great decrease in the occurrence of severe losses.

Ruffle Leaf of Tobacco. S. G. LEHMAN. In August, 1937, many tobacco plants showing striking leaf malformations were found near Raleigh, North Carolina. On affected plants leaf-blade development is repressed in varying degrees causing some leaves to appear petiolate, others string-like. Leaf margins turn downward in a narrow tight roll, while the blade as a whole may fold upward along the midrib. Veins frequently coalesce, binding and making the margin appear crenate. V-shape accessory laminae, "Ruffles," grow downward from the lower side of leaves whose blades are not too strongly repressed. Neither chlorosis nor necrosis occurs, but diseased leaves usually appear greener and thicker than normal leaves. Stem elongation usually is not repressed, nor do axillary buds show abnormal tendency to grow into suckers. Accessory flower parts develop. Affected plants set seed abundantly. Attempts to transfer the malady by mechanical inoculation, by insect vectors, and by grafting have given only negative results.

The Source of Nitrogen and Accessory Growth Factors in the Nutrition of Some Fungi. LEON H. LEONIAN and VIRGIL GREENE LILLY. According to their ability to utilize different sources of nitrogen, some 40 representative fungi were divided into the following groups: 1. Those utilizing the nitrogen of ammonium salts, of nitrates, and of amino acids without the aid of vitamin B_1. 2. Those utilizing ammonium and amino acid nitrogen but not nitrate nitrogen. 3. Those utilizing amino acid nitrogen but not ammonium nitrogen. 4. Those utilizing either ammonium or amino acid nitrogen but only in the presence of vitamin B_1. (1 p.p. 20 million.) 5. Those capable of using amino acid nitrogen but not ammonium or nitrate nitrogen in the presence of vitamin B_1. 6. Those that seemed incapable of utilizing any of the foregoing sources of nitrogen, either in presence or absence of vitamin B_1. Fractionation of yeast extract has yielded a concentrate that induced good growth in this and all groups of fungi tested. Pure crystals of vitamin B_2 (lactoflavin) could not replace vitamin B_1 and manifested a comparatively slight catalytic property. Although vitamin B_1 is a controlling factor in the growth of several fungi, under certain conditions it was replaced by substances devoid of vitamin B_1. Also, it seems possible that the essential amino acids may be replaced by other materials whose exact nature is still unknown. Whether such substances consist of amino acids in combined form, or contain some catalytic materials other than the known vitamins, remains to be determined.

Potential Agents of Biological Control of Plant-parasitic Nematodes. M. B. LINFORD and J. M. OLIVEIRA. Soil populations of plant-parasitic nematodes are influenced by an unstable, interacting complex of diverse parasites and predators. Recognition of components and partial analysis of their interactions have been facilitated by transparent, low-nutrient media containing nematodes. By sampling chiefly roots and soil from Hawaiian fields and gardens infested with the root-knot nematode (*Heterodera marioni*), the writers have, since October, 1935, collected 52 enemies of this pathogen, most of them attacking also *Pratylenchus pratensis* and many other nematodes, and some attacking one another. All but *Mononchus* spp. and one mite, in the following list, have been new records for Hawaii: Eleven nematode-trapping fungi (Phycomycetes and Hyphomycetes), 1 egg parasite (*Penicillium* sp.); 6 non-trapping parasites (*Chytridiales, Ancylistales,* and Hyphomycetes); 1 ecto-parasitic protozoan; 24 predacious nematodes (5 *Aphelenchoides,* 2 *Diplogaster,* 14 *Dorylaimidae,* and 3 *Mononchus*); 6 mites; and 3 predacious tardigrades (*Macrobiotus*). Some of these have been found in sand, volcanic ash, forest litter, and soil from sea level to 9,700 feet, but, where *H. marioni* is established, several are wide spread and abundant; 18 species have been collected within half a mile. Normal activities of these agents restrict nematode populations, but practical biological control awaits means of increasing these activities.

Root-knot Injury Restricted by a Nematode-trapping Fungus. M. B. LINFORD and FRANCIS YAP. An experiment, involving 10 treatments of 10 5-gallon pots each, compared

plant growth during 15 months in steamed soil as follows: A and B, without nematodes; C and D, with *Heterodera marioni*; and E and J, with nematodes plus 6 isolates of nema-trapping Hyphomycetes grown in a nutrient-bagasse medium. Sterile begasse medium was added to B and D; *H. marioni* larvae were added, 490 per pot, to all but A and B; and these two were infested with desiccation-tolerant flora and fauna separated from the nematode suspension. Nematode infestation reduced pineapple top growth as follows: 40 per cent without bagasse, 34 per cent with bagasse, and only 28 per cent with bagasse plus *Dactylella ellipsospora*. Reductions in total root length were 73, 69, and 57 per cent, respectively. *Arthrobotrys oligospora* (2 isolates), *A. musiformis*, *Dactylella* sp., and *Dactylaria thaumasia* were without apparent effect. Chance infestations of an egg parasite (*Penicillium* sp.) accompanied *H. marioni* throughout and, among C and D plants, 14 of 17 sampled were contaminated with trapping fungi; consequently, the full degree of biological control was not measurable. Reisolations from galled roots showed that species of trappers, introduced experimentally, remained dominant during 15 months.

Growth Tests with Extracts of Erwinia amylovora, Phytomonas rhizogenes, Taphrina cerasi, T. deformans, and Ustilago zeae. GEORGE K. K. LINK, HAZEL W. WILCOX, and VIRGINIA EGGERS. Dextrose-tryptone, and dextrose-tryptone-peptone broth cultures of each of these organisms were adjusted to pH 2.5 with 2N HCl and filtered through pyrex wool. Glass and residue were frozen with solid CO_2, ground, while frozen, and added to the filtrate. Each lot was divided into 125 cc. samples. Each sample was extracted for 9 hours with peroxide-free ether in an apparatus devised by Gallagher, Koch, and Dorfman for quantitative extraction of sex hormones from small samples of urine. Extraction by shaking with ether also was tried. Crude extracts of each lot were tested for auxones by application to intact coleoptiles of Avena and to intact hypocotyls and internodes of *Phaseolus vulgaris*. Extracts obtained by shaking were found inactive. Those obtained by use of the extractor produced growth responses in the treated plants. These results warrant the conclusion that each organism tested produces one or more auxones and that these may be parts of chemical mechanisms by which these parasites disturb growth of their hosts. The Salkowski test indicates β-indoleacetic acid as a constituent of each extract.

Growth Substance in Crown Gall. S. B. LOCKE, A. J. RIKER, and B. M. DUGGAR. Responses of inoculated plants, such as epinasty of petioles, increased initiation of adventitious roots, increased cambial activity, suppressed development of axillary and adventitious buds, and delayed abscission of petioles, which indicate the presence of growth substances, were induced to a greater degree by a virulent culture of *Phytomonas tumefaciens* than by an attenuated sister single-cell culture. The attenuated culture stimulated the development of adventitious shoots. Tomato stems inoculated with the virulent culture yielded, during at least 10 days immediately following inoculation, more growth substance than comparable noninoculated tissue, as measured by Went's diffusion method. Three per cent beta-indole-acetic acid in lanolin, applied to the tips of decapitated tomato stems, was less effective than substances diffusing from galls induced by the virulent culture in stimulating proliferation about inoculations with the attenuated culture in the stem below. Efforts to differentiate virulent and attenuated cultures on the basis of growth substance produced in culture have thus far been unsuccessful. The similar growth rates, based on frequent counts of virulent and attenuated cultures in tomato stems, suggest that there is no selective bacteriostatic action of the host.

Influence of Temperature and Humidity on Powdery Mildew of Roses. KARLA LONGRÉE. Temperature studies on conidia on rose leaves indicated for germination: minimum 3°–5° C., optimum 18°–24° C., maximum 33° C.; for mycelial development: minimum 6° C., optimum 18°–24° C., maximum 27° C.; for sporulation: minimum 9° C., optimum 18°–24° C., maximum 27° C. At temperatures just above the optimum, spores mature and age rapidly; below, maturing is slow and germinability preserved longer. Detached spores die readily with increased temperatures and decreased humidities. Free water decreases germination. Great difficulties were experienced in obtaining relative humidities close to 100 per cent without getting condensation, but this was finally accomplished through precise temperature control. It was found that the relative humidity need not be higher than about 97 per cent in order to give excellent germination but that, above and below 95 per cent, germination is close to zero and ceases below 75 per cent. In comparing germination of conidia on glass slides and on leaves of rose shoots, kept also under controlled conditions, it was concluded that the relative humidity at the surface of young rose leaves is very high, even in a dry atmosphere.

Phycomycetes in Iowa Soil. CLIFFORD H. MEREDITH. An examination of 20 types of cultivated soils in the northern, central, and southern parts of Iowa revealed the pres-

ence of many rapid-growing, nonseptate fungi. These were obtained from 1 g. lumps of soil placed in a Petri dish of plain agar. The tip of the most rapid-growing organism was freed from bacteria by placing it under plain agar in a plate and taking the fungus off when it grew to the surface. Six of these were identified as *Pythium de baryanum*, *P. pulchrum*, *P. rostratum*, *P. ultimum*, *P. graminicolum*, and *Aphanomyces* sp. In April and May, 1936, species of *Pythium* predominated in the soils under observation. In July and August fewer isolates of phycomycetous fungi were obtained. In April, 1937, 10 isolations from each of 5 soils yielded 50 cultures of Phycomycetes, with *Pythium de baryanum* predominating. Isolations made from soils in corn fields the first of July yielded a high percentage of pythiaceous fungi; while isolations made the last of July, following a hot, dry period, gave few species of *Pythium*.

Fusarium avenaceum, a Vascular Parasite of Potato. JOHN G. MCLEAN. A disease of potato caused by *Fusarium avenaceum* was first observed in Wisconsin in the summer of 1936 and has since been collected throughout the State. The fungus is definitely pathogenic, penetrating the roots and producing a seed-piece decay. Symptoms vary with time of infection, soil and air temperature, and soil moisture. Tuber symptoms resemble those of the more common potato wilts. Top symptoms differ from those produced by *F. solani* v. *cumartii* and *F. oxysporum*. There is a reduction of leaf area due to the decrease in size of the leaflets on apical leaves and an increase in the number of folioles. The axillary buds are stimulated into production of secondary shoots or aerial tubers. Chlorosis and tipburn are typical, along with rigidity of stem and petiole. The leaves roll upward and assume a harsh texture. Reddening or purpling of the tops is not uncommon. Cobblers, Triumphs, Katahdins, and Rurals are susceptible. Early varieties are more apt to escape the disease.

The Relation of Nitrogen Nutrition to Virulence in Phytomonas stewarti. GEORGE L. MCNEW. Ten strains of *Phytomonas stewarti* that differed in virulence were tested for differences in physiology, including ability to use inorganic nitrogen. Virulent cultures grew readily when seeded on an agar medium containing ammonium nitrate as the only source of nitrogen, but weakly virulent ones failed to produce visible colonies unless organic nitrogen was added. Of 510 single-colony isolates that were seeded on the synthetic medium, all the virulent ones grew readily; but many of the weakly virulent ones grew sparsely, if at all. When these weakly virulent cultures were induced to grow on the medium, they gained in virulence. Conversely, if the cultures were restored to virulence by host passage, they gained ability to use inorganic nitrogen. Of the 10 original strains tested, only the most virulent one reduced the nitrates in the synthetic medium to nitrites. Nitrites were also identified in wilted plants inoculated with either this or other highly virulent cultures. As has been demonstrated for other wilt diseases, nitrite solutions caused wilting when injected into healthy plants. However, *Phytomonas stewarti* may cause severe wilting without producing nitrites when inoculated plants grown in sand are deprived of nitrates and supplied only with ammonium nitrogen.

Distribution of Bacterial Cells in Poured Plates. GEORGE L. MCNEW. In order to determine if the dilution-plate method is reliable for securing single-cell cultures, observations were made on the distribution and growth of bacterial cells in agar. Agar from dilution plates seeded with broth cultures was sliced, stained, and examined under oil immersion. In plates inoculated with *Phytomonas stewarti*, 99.0 $\pm$ 0.35 per cent of the points occupied by the bacteria were seeded by single cells. The isolated cells grew readily when incubated under aseptic conditions. Most of them divided within 3 hours and their progeny about every 1½ hours thereafter. In 2 preparations only 6.5 and 11.3 per cent of the single cells failed to divide within 22 hours. Similar results were secured with 3 other strains of *Phytomonas stewarti* and with *P. translucens* var. *undulosum*, *P. campestris*, *P. phaseoli*, *P. angulatum*, *P. savastanoi*, *P. pisi*, *P. tabacum*, *P. pruni*, and *Erwinia carotovora*. The percentage of single cells was lower (90 to 97) with *P. michiganensis*, *P. juglandis*, *P. tumefaciens* (3 stains), and *P. insidiosum*. *P. fascians* was the only species in which clumping of cells occurred extensively. There was no evidence that the melted agar caused agglutination, since the clumps existed in culture before the bacteria were suspended in agar.

A New Race of Crown Rust That Attacks Bond Oats. M. B. MOORE, A. R. DOWNIE, and H. C. MURPHY. An apparently new race of *Puccinia coronata avenae* has been found that differs from Murphy's race 1 in that Bond, a variety used extensively in breeding for crown-rust resistance, is susceptible. Two collections were made in the spring of 1937 in Texas. These collections, together with race 1, previously obtained from H. C. Murphy, were increased in the greenhouse and used for inoculation in the oat-breeding nursery at University Farm. Subsequently, an epidemic of crown rust developed on Bond and its

hybrids. The Bond race may have originated in either of the two Texas collections or as a mutant or mixture in the material obtained from Murphy.

Fusarium Yellows of Gladiolus. RAY NELSON. A destructive disease of field plants and stored corms of gladiolus is apparently of general occurrence in the commercial producing sections of the United States and has recently attained major importance. Losses have been heavy in some areas, in some instances forcing the abandonment of large acreages of infested soil. The field aspects are those of a systemic vascular mycosis and include, most typically, dwarfing of the plant and progressive yellowing and dying of the leaves. Losses from decay in stored corms grown on infested soil have been excessive, exceeding $10,000 in one cellar in 1937. Various types of corm decay occur, including a circumscribed core rot and a spongy decay of the flesh that originates from infected vascular strands. Surface decay is usually initiated only at nodes where these strands terminate. The causal relation of a section Elegans *Fusarium* isolated from infected plants and corms has been established in numerous experiments. The temperature relations of the pathogen and the effects of temperature and moisture on the disease have been studied and are essentially like those reported in other fusarial mycoses. Varietal reactions vary from complete susceptibility to apparent immunity. Most of the leading commercial varieties are susceptible.

Dissemination and Viability of Conidia of Peronospora destructor. A. G. NEWHALL. Negative results in the control of onion mildew were obtained in 1937 by hot-water seed treatments in western New York. Field observations indicated distant sources of windborne inoculum. Surveys have shown that primary sources could be top-set or winter onions, often grown in small town gardens. Many such plantings were found sporulating in May several weeks before field infections on the commercial crops could be found (June–July). Wind-borne conidia were caught July 15 on slides exposed overnight ½ mile from the nearest onions. During an airplane flight, August 1, over infected onion fields, 132 conidia were caught on plain agar Petri-dish spore traps exposed at 6 levels up to 1500 feet, the upper limit of this test. Of these, 100 germinated normally in a few hours. That such spores are important in disseminating mildew is indicated by laboratory tests, which have shown some conidia can remain viable on glass slides held for 3 days at 70 per cent relative humidity and 15° C. and for 5 days at 9° C. Some germinated after being frozen 15 hours. They withstood 7 hours' exposure to September sunshine in drops of cold water. Malachite green inhibited spore germination much better than copper sulphate.

The Application of Electrodialysis to the Study of Copper Fungicides. A. A. NIKITIN. A study was made to correlate the chemical composition to the behavior of the copper compounds when used as fungicides. Electrodialysis methods as used in the study of soils were adapted to this purpose. From the character of a deposit, variation of current and temperature, certain deduction can be made concerning the behavior of the copper compounds for agricultural purposes. The rate of decomposition is related to the character and composition of the compound. This rate may be evaluated by observation of the change of pH in the cells, the time required for discoloration of the deposit, and the change in the character of the dispersed phase. By the use of electrodialysis it is possible to determine the effect of various acid radicles on the chemical behavior. The degree of discoloration of the deposit on the diaphragm has been found indicative of the character and composition. Furthermore, the adhesiveness and spreading properties of a fungicide can be, in most cases, estimated from the degree of adherence of the deposit to the diaphragm. It seems that electrodialysis helps to establish the facts of importance in understanding the action of copper fungicides.

Studies on the Efficiency of Colloidal Copper Fungicides. A. A. NIKITIN. The fungicidal efficiency of a copper compound depends upon interrelated chemical and physical properties. It has been found that the principal factor responsible for most of such efficiency is a colloidal state. For instance, colloidal-copper compounds, when applied to foliage, have shown little if any tendency to cake, scale, or wash off. Also, uniformity of composition may be most easily attained when the material is prepared as a colloid. Experiments have shown that the colloidal state, to have beneficial characteristics, must be formed in the initial precipitation of the fungicide. When it is formed by mechanical treatment of a crystalline phase or is induced by the addition of spreading agents, these properties are largely lacking. Studies on the compatibility of copper compounds with arsenicals with and without lime have shown that the colloidal state inhibits the chemical and physical changes that usually occur when the material is in the ordinary crystalline condition.

Differentiation of 5 Mosaic Viruses of Legumes. H. T. OSBORN. Pea virus 1, pea virus 2, vein mosaic of red clover, a virus from white clover, and a virus from white sweet

clover were studied in *Vicia faba* and other hosts. Certain distinctive characteristics serve to differentiate these viruses. Pea virus 1 causes enations to develop on pea and crimson clover. Transmission by the pea and potato aphids requires an incubation period in the vector. Pea virus 2 comprises a group of strains from which the Perfection variety of garden pea is immune. Transmission by known aphid vectors is without an incubation period. Vein mosaic of red clover is characterized by symptoms produced along the veins in several legumes. Transmission by the pea aphid is without an incubation period. The virus from white clover produces distinctive necrotic primary lesions on mung bean. The virus from white sweet clover differs from the 4 preceding viruses in that it is transmissible to solanaceous hosts. It causes necrotic primary lesions on bean, mung bean, and cowpea. Necrotic primary lesions are followed by systemic infection in *V. faba* and tomato. It differs from Price's ring spot 2 and a California strain of spotted wilt of tomato, which were transmitted to *V. faba* for comparison.

Soil Rot of Sweet Potatoes in Louisiana. L. H. PERSON. Soil rot of sweet potatoes, first noted in the Sunset sweet-potato district of Louisiana in 1934, has since increased in severity. In 1936 several fields were a total loss. During the growing season of 1937 a systematic survey of the sweet-potato area showed the disease much more widespread and destructive than was formerly thought. In some sections examined it was so severe that entire fields were abandoned. The symptoms are very characteristic, the plants being stunted, with small, thin, pale green to bronze leaves. The root system is badly rotted, and in heavily infected areas the plants fail to grow; many die before the end of the season. From 1 year's tests sulphur applied to the soil at the rate of 700 and 1,000 pounds per acre has given very promising results. Applications of 400 lbs. were ineffective. The pH of the soils varied from 5.7 to 6.0 before the sulphur was applied and dropped to 4.9 to 5.2 after sulphur applications. The yields per acre of grades 1 and 2 on duplicate plots were as follows: Check, 1.6 bushels; 400-pound rate, 21.0 bushels; 700-pound rate, 94.5 bushels; and 1,000-pound rate, 112.22 bushels.

Potato Spraying Experiments in Louisiana in 1936–1937. MILTON A. PETTY, JR.

The Effect of Flue-curing on the Survival of Ordinary Tobacco Virus 1. J. A. PINCKARD. Air and leaf temperatures at various points in 12 barns of flue-cured tobacco were studied in relation to the survival of the mosaic virus naturally present in the leaves. By frequent removal of standardized samples and their subsequent inoculation into tobacco plants, it was possible to determine the approximate temperature and exposure required to inactivate the virus. The virus survived the curing process throughout 4 of the first 5 barns cured and in the lower and middle tiers of the fifth barn. Temperatures of the lower tiers were from 191° to 196° F. for not more than 7 hours during final drying. In the remaining 7 barns, and even though final drying temperatures of 193° to 208° F. were maintained in the lower tiers for several hours, the virus was not inactivated in certain other portions of the barns where the temperatures varied as much as 50° F. These results show that the flue-curing process of primed tobacco is an uncertain means of virus inactivation and that flue-cured tobacco may become a dangerous source of primary infection if used by growers while preparing for succeeding crops.

Bacterial Wilt and Rot of Potatoes. H. N. RACICOT and D. B. O. SAVILE. Sets from diseased tubers planted in field plots, of which 75 per cent germinated, produced 79 per cent diseased plants. Sets from healthy tubers needle-inoculated around the eyes with a suspension of the causal organism, of which 98 per cent germinated, produced 97 per cent diseased plants. Sets with cut surfaces waxed, then dipped into suspension, of which 100 germinated, produced 34 per cent diseased plants. Sets cut with a knife purposely contaminated by cutting diseased tubers, of which 97 per cent. germinated, produced 97 per cent. diseased plants. Tubers dipped into suspension, dried, then cut into sets, of which 99 per cent grew, produced 54 per cent diseased plants. Tomatoes, eggplants, and peppers were successfully inoculated with the causal organism. The following did not become infected: *Solanum capsicastrum, S. dulcamara, Petunia hybrida, Nicotiana tabacum, Physalis pubescens* (husk tomato), and *P. heterophylla.*

Cell Stimulation by Chemicals in Relation to Crown Gall. A. J. RIKER and R. NAGY. A number of substances were mixed with lanolin and applied to decapitated test plants for determining their activity in stimulating cell growth. The substances included (1) living and lyophilized crown-gall bacteria and extracts from them; (2) culture filtrates and several metabolic fractions; (3) lyophilized tomato crown gall and lyophilized uninfected tomato stems; (4) beta-indole-acetic acid; (5) methyl cholanthracene and 1, 2, 5, 6 dibenzanthracene; and (6) several miscellaneous compounds, including vitamin B_1. (This last substance is produced from synthetic media by crown-gall bacteria in a quan-

tity comparable to that by yeast). Test plants included primarily bean and sunflower, but tomato, Coleus, and Impatiens also were employed. In general, the beans showed a distinct but variable response to many of the materials, especially those in groups (1) to (4), inclusive, while the sunflower reacted to very few. On beans 3 per cent beta-indole-acetic acid, renewed every week, induced the greatest proliferations, while, on the other plants, those from crown-gall inoculations were largest.

The Problem of Breeding Rice for Resistance to Cercospora oryzae. T. C. RYKER. About 75 per cent of the rice acerage in Louisiana is planted to the varieties Blue Rose and Early Prolific. These varieties are highly susceptible to Cercospora leaf spot, Ordinarily, Early Prolific, because of early maturity, is not seriously affected, while Blue Rose, which matures considerably later, is. All fields of the latter variety are usually rather uniformly infected. When the infection is severe a premature browning and dying of the plants occur. Certain commercial varieties, such as Rexora and Fortuna, are highly resistant, but even these tend to become susceptible when maturing. A study of the inheritance of resistance is complicated by the facts that all degrees of resistance from highly susceptible to highly resistant occur and that susceptibility varies with the maturity of the plants. A method of inoculation has been employed that apparently permits selection for resistance. Several selections made in Blue Rose in 1936, when tested in the field in 1927, appeared to be resistant.

Attenuation of Crown-gall Bacteria. A. J. RIKER, J. VAN LANEN, and I. L. BALDWIN. The bacteriological character responsible for the pathological cell stimulation induced by *Phytomonas tumefaciens* has been studied through attempts to change this property. Single-cell isolates have remained apparently unchanged in pathogenicity when kept for seven years in stock culture media. However, about 10 (sometimes more) culture generations in similar media containing 0.1 and 0.3 per cent glycine commonly attenuate these cultures. Glycine is relatively toxic and the smaller quantities are used until some tolerance is developed. The loss of pathogenicity is faster at pH 8.0 than at 6.0. A few cultures have regained pathogenicity in part or completely when restored to stock media. However, a number of them have remained attenuated for two years. Non-virulent strains appear similar to pathogenic sister cultures in colony characters, dye absorption, and reactions in differential media. The utilization of glucose and glutamic acid indicates that growth of the attenuated glycine acclimatized cultures is somewhat less than that of the sister pathogenic cultures. Of approximately fifteen related compounds only glycine, alanine, glycylglycine, and to some extent, dicyandiamid, cause loss of virulence.

Centrifugal Movement of Ceratostomella ulmi in Inoculated American Elms. S. L. SMUCKER. Young American elms held in a greenhouse under quarantine conditions were inoculated in incisions near the base of the stems in the spring of 1936. The trees were held through 2 growing seasons. No elm bark beetles or leaf-feeding insects were permitted to attack the trees at any time during the experiment. Seven to 70 days after inoculation 34 per cent of the trees developed active symptoms of disease. No trees were entirely killed the first season. The second growing season after inoculation 2.6 per cent of the trees that had active symptoms of disease the first year developed wilt and die-back. *Ceratostomella ulmi* was inoculated from a high percentage of all the inoculated trees from which cultures were made the second year. These preliminary results were obtained under controlled conditions in the greenhouse and no attempt is now made to extend an interpretation of them to field conditions.

A Fusarium Foot Rot of Cucurbita. WILLIAM C. SNYDER. A destructive foot rot has been observed in California on *Cucurbita pepo, C. moschata, C. maxima,* and certain varieties of these species. Italian Zucchini squash is particularly susceptible, but all of the many varieties of squashes, pumpkins, and gourds tested have succumbed. The disease occurs mostly in the coastal counties, and losses have ranged up to 75 per cent of the stand. There are indications that seed may serve as a carrier of the disease. Symptoms appear as yellowing and browning of the lower leaves and, finally, drooping of all leaves and wilting of the plant. The rot involves primarily the cortical tissues of the stem near the ground level but may proceed deeper and sever the plant completely from the roots. Fruits also may become infected. The causal fungus is a Fusarium belonging to Section Martiella. Single-spore cultures used in pathogenicity tests have proven the organism highly virulent. Susceptible plants grown in sterilized soil have developed symptoms within 2 weeks after watering the soil with a spore suspension of the fungus. Through manipulation of cultures it has been possible to obtain the perfect stage of the pathogen readily. This is found to fall in the genus *Hypomyces* of the Hypocreales.

The Epidemiology of Stem Rust of Wheat in Three Successive Contrasting Years. E. C. STAKMAN, W. T. BUTLER, R. U. COTTER, and J. J. CHRISTENSEN. Favorable weather permitted abundant uredial development in the North in the fall of 1934. Timely winds carried spores southward, and numerous infection centers developed, especially in early sown fields. Direct and circumstantial evidence indicated uredial overwintering in 8 per cent of wheat fields examined in Texas. Superabundant late-spring rainfall and delayed maturity of wheat in northern Texas and late wheat and "rust weather" in parts of Kansas and Nebraska favored abnormally heavy rust development. Favorable winds for northward dissemination of urediospores, late spring grain, ideal rust weather, and virulent physiologic races combined to cause a devastating epidemic in spring wheat. The uredial stage survived the 1935–36 winter in 2 per cent of Texas wheat fields examined. Spores were blown northward early, in May and June, but heat and drought prevented an epidemic. In 1936–37 uredial overwintering was negligible in Texas and northern Mexico, but inoculum was abundant farther south. Rust appeared and multiplied rapidly in northern Mexico, northern Texas, and beyond. Northward, repeated, heavy spore showers; rust weather; late, heavy wheat stands; and virulent rust races contributed to a wide-spread epidemic.

The Increase and Importance of Race 56 of Puccinia graminis tritici. E. C. STAKMAN and R. C. CASSELL. There have been pronounced recent shifts in population trends of several physiologic races, but the origin, extension in geographic distribution, and increase in prevalence of race 56 are most significant. Found first and only in Iowa, Kansas and Nebraska in 1928, it is now generally distributed throughout the United States and northern Mexico (in Canada also, according to reports of Dominion Rust Research Laboratory). It constituted 1 per cent or less of uredial isolates identified by the writers in the United States from 1928 to 1931, inclusive. The percentages since then follow: 1932, 2.1; 1933, 3.7; 1934, 33.1; 1935, 44; 1936, 47; 1937, 56 (to November 1). There is evidence that race 56 originated on barberry and that it was largely responsible for the collapse of Ceres wheat, moderately to highly resistant to stem rust prior to 1935. In 1937, race 56 constituted approximately 70 per cent of the isolates obtained from Ceres. That the aecial stage continues important in the origin and persistence of races is shown by the fact that from 1935 to 1937, inclusive, a different race was identified in every 6.5 aecial isolates, while the ratio for uredial isolates was 1:59. (U. S. Department of Agriculture and Minn. Agr. Exp. Sta.)

The Gymnosporangium Rusts in Maine. F. H. STEINMETZ and ALTON E. PRINCE. The Gymnosporangium rusts have been under observation since 1931. Their importance was accentuated by the occurrence of *Gymnosporangium clavipes* on certain varieties of apples. More recently these rusts have come to the attention of property owners as diseases of ornamental trees and shrubs. Eleven species of Gymnosporangium rusts have been collected in the aecial and telial stages on native host plants. They are here listed and numbered for reference in this abstract. 1. *G. clavariaeforme*, 2. *G. clavipes*, 3. *G. aurantiacum*, 4. *G. davisii*, 5. *G. ellisii*, 6. *G. biseptatum*, 7. *G. transformans*, 8. *G. juniperi-virginianae*, 9. *G. globosum*, 10. *G. corniculans*, 11. *G. nidus-avis*. The telial stage of species 1, 2, 3, and 4 was collected on *Juniperus communis* var. *depressa*, a widely distributed host. The telial hosts of the remaining rusts are local in Maine. The same stage of species 5, 6, and 7 was collected on *Chamaecyparis thyoides*, while species 8, 9 and 11 were collected on *J. virginiana* var. *crebra*. Species 10 has been found on *J. horizontalis* only, while species 11 has been found on *J. horizontalis* and *J. virginiana* var. *crebra*. *G. clavipes* is widely distributed and is of greatest economic importance to apple growers in Maine.

The Copper Factor in Bordeaux Injury. R. F. SUIT and JAMES G. HORSFALL. From various experiments conducted to compare the efficiency of insoluble copper fungicides with that of Bordeaux mixture, it is indicated that the copper factor in Bordeaux is responsible for certain kinds of injury. From results obtained on apples, cucurbits, peaches, and Lima beans it is shown that the insoluble copper fungicides produce more leaf spotting than does Bordeaux. Further, in the case of apples, there is less fruit russet from Bordeaux. From data on cherries and tomatoes it is apparent that copper is responsible for some defloration. There are also results indicating that copper may accelerate transpiration. Copper injury of Lima beans is somewhat reduced by use of zinc dust, sulphite lye, or lime, and markedly so by magnesium oxide. Copper injury seems to be increased with dosage, solubility, and electrolytic dissociation of the compound and its tenacity to the plant. However, in various experiments, plants sprayed with Bordeaux have shown a stunting, deformation of leaves, reduced yield, or other symptoms not produced when Bordeaux substitutes were used. This would indicate certain symptoms are associated with Bordeaux injury that cannot be ascribed to the copper factor.

Observations on Nematodes of Buffalo Grass and Sorghum. GERTRUDE TENNYSON.

Effect of Mixed Inocula on the Production of Seedling Blight of Flax. IAN W. TERVET. Investigations on the possibility that weakly parasitic strains of *Fusarium lini* were mainly secondary organisms following upon the attack of fungi known to cause rotting in flax roots yielded negative results. Flax seedlings, grown in steamed soil in which cultures of *F. lini* had been mixed with isolates of several root-rotting fungi (*Helminthosporium* spp., *Rhizoctonia solani, Ophiobolus cariceti, Thielavia basicola*), showed a delayed emergence and a retardation of wilting. However, the attack of a very virulent strain of *F. lini* was completely changed by the presence in the soil of *Chaetomium* sp. Seedlings of Winona flax normally were killed by this strain of *F. lini* within one week after emergence, but, after 24 days in the soil with mixed inoculum, many plants were still alive. The root systems of the surviving plants were malformed, with short swollen lateral roots somewhat resembling the mycorrhiza of *Pinus*, while the stem internodes were very short and the foliage dark green. One-third of the plants survived until flowering time, although they were extremely dwarfed.

Further Work on Purification of Tobacco Mosaic Virus. CARL G. VINSON.

Soil Temperature in Relation to Potato Yellow Dwarf. J. C. WALKER and R. H. LARSON. Epidemics of yellow dwarf in central Wisconsin have been characterized by poor stands rather than high percentages of plants showing systemic symptoms. The major crop often is exposed to high temperatures in the light, sandy soil during and immediately following planting in the first half of June. Experiments were conducted in soil held at constant soil temperatures of 16°, 20°, 24°, and 28° C., and a common air temperature of 20–22° C. Infected seed tubers were cut into 4 pieces and one piece planted at each temperature. At 16°, normal germination was followed by development of plants indistinguishable from the control. At 20°, emergence was normal but plants were slightly dwarfed. At 24°, emergence was reduced and severe symptoms occurred. At 28°, there was almost no emergence. Seed pieces in nonmerging hills usually remain firm for several weeks, often until harvest. Even after that period, they commonly germinate normally in cool soil.

Present Status of Azalea Flower Spot. FREEMAN WEISS and FLOYD F. SMITH. This disease, caused by *Ovulinia azaleae* n.g. et n.sp. occurs throughout the South Atlantic and Gulf Coast region from Wilmington, N. C., to central Louisiana. It chiefly affects cultivated azaleas of the Indian and Kurume groups. Native azaleas, though susceptible, have not been found infected in nature. Environmental requirements for infection parallel the conditions favorable for host blooming and are approximately satisfied in both greenhouse and outdoor azalea culture whether in the South or North. The pathogen is disseminated by the transportation of infected blooming plants and also, apparently in the soil, with non-blooming plants. Its survival between flowering seasons outside its present range has not been demonstrated. Several native plants besides azaleas, including rhododendrons, *Kalmia*, and *Vaccinium* spp., are potential hosts. Satisfactory control under nursery conditions was obtained by semi-weekly applications of copper-kaolin dust throughout the blooming season, but this is not a practicable control in show gardens. Insects were apparently not responsible for initiating primary infections on azaleas, but became efficient carriers during the height of bloom, and can be important factors in spreading the disease throughout a planting, or introducing it into nearby plantings. Abrasion of flowers by bees does not promote infection. Insects most important in dissemination of flower spot are *Apis, Bombus, Emphoropsis* and *Xylocopa.*

Effect of Phytomonas flaccumfaciens, Phyt. insidiosa, Phyt. michiganensis, Phyt. campestris, Phyt, panici, and Phyt. striafaciens on Maize. E. J. WELLHAUSEN. Effect of above organisms was determined on 2 inbred lines of maize, one (GB797) very susceptible and the other (OSF) very resistant to *Phyt. stewarti.* Infection of very young seedlings of these 2 lines was obtained with each of the organisms. Each seemed to attack GB797 more readily, with the exception of *Phyt. insidiosa,* which caused more infection on OSF. Infection of either host was primarily confined to the xylem vessels of the vascular bundles. No brown, water-soaked lesions, characteristic of infection with *Phyt. stewarti,* were produced. *Phyt. flaccumfaciens* usually caused a high degree of infection on GB797. Seedlings were generally severely dwarfed and often a few were killed. *Phyt. insidiosa* had a similar effect on OSF. Infection of the 2 maize lines by the other organisms was much milder. *Phyt. campestris* and *Phyt. striafaciens* had practically no effect on OSF. *Phyt. stefarti* was tried on the common hosts of some of the organisms tested on maize. Golden Cluster beans were slightly infected. Proso millet and Early Pearl

oats were readily attacked. Noso infection on Bonny Best tomatoes or Early Jersey Wakefield cabbage was detected.

Early Blight of Tomato in Wisconsin. O. C. WHIPPLE.

Two Strains of Cucumber Virus on Pea and Bean. O. C. WHIPPLE and J. C. WALKER. One virus (408) was recovered in 1935 at Madison, Wisconsin, from naturally affected peas and beans growing in the open, while the other (729) was recovered from peas in a commercial greenhouse. Strain 408 produced symptoms on tobacco and cucumber similar to *cucumber virus 1;* 729 produced a mild mottle on tobacco and symptoms on cucumber similar to *celery virus 1.* By transfer of expressed juice from tobacco infected with 408, symptoms resulted on 21 species in 5 families, including 4 varieties of *Pisum sativum,* and 39 varieties of *Phaseolus vulgaris* including some of the latter resistant to *bean virus 1.* All hosts of *cucumber virus 1* tested were susceptible. Mottling of leaves of young plants and mild streaking of stem were produced on pea. Distinct mottling, leaf distortion, and stunting occurred on bean and, with one substrain, a severe streak. Strain 729 caused leaf necrosis on pea, but no symptoms on bean. Its host range closely parallels that of *cucumber virus 1.* Both 408 and 729 are transmitted by *Myzus persicae* and are similar to *cucumber virus 1* in their point of inactivation through ageing *in vitro,* dilution, and heating.

Further Tests of Rosin-lime Sulphur as a Fungicide. C. E. YARWOOD. In 1937 field tests of fungicidal control of snapdragon rust, in which rosin-lime sulphur, lime sulphur + spreader, sulphur dust, cottonseed oil, and lime sulphur + cottonseed oil were employed, 1 per cent rosin soap + 1 per cent lime sulphur was the most effective spray, reducing the rust infection from 44 pustules per leaf on the checks to less than 4 per leaf on the treated plants (4 check and 4 treated plots) and increasing the yield from 620 mg. per plant on the check to 1620 mg. per plant on the treated plants. In field tests of fungicides for the control of onion downy mildew, rosin-lime sulphur was superior to Bordeaux + spreader, lime sulphur + spreader, or Palustrex copper compound. In the greenhouse, rosin-lime sulphur, applied to the lower surface of bean leaves, greatly reduced the mildew infection on the upper surface of the same leaves.

The Effect of Boron Nutrition on the Susceptibility of Some Plants to Powdery Mildews. C. E. YARWOOD. Under conditions of heavy artificial inoculation, check sunflower plants in Hoagland solution minus boron were severely stunted and heavily mildewed, while plants with 1 and 10 parts per million of boric acid made a normal growth and were much less mildewed in most tests. The addition of boric acid, up to toxic quantities to sunflowers in greenhouse soil not deficient in boron, had no specific effect on the mildew susceptibility of the plants. The addition of boric acid to water cultures of beans, cucumbers, and oats, and to soil cultures of beans had no marked effect on the mildew susceptibility of the plants.

Some Diseases in Forest Plantings of White and Red Pine in Western New York. HARLAN H. YORK. These plantings have been established for 20 to 30 years. Until 1929, when disease first became evident, they were fully stocked. The plantings consist of a single species and the rate of growth of the trees is above the average for each species. The determination of the more important predisposing factors is being attempted. The damage from *Polyporus schweinitzii* and a resinosis is so severe that it is doubtful whether the trees in plantings having a total area of over 1000 acres will reach maturity. These disturbances are most destructive in soils of high pH and colloidal content and where there is a slow or poor humification of the duff. *Polyporus schweinitzii,* if not distributed from nurseries, may attack trees within a very few years after the plantings are established. It has been isolated from the roots of northern white-pine trees that had been in the plantings 7 years.

Weighted Percentages of Resistance of Tomato Varieties to Fusarium lycopersici. P. A. YOUNG and J. J. TAUBENHAUS. Wilt resistance of tomatoes was tested extensively in 3 fields under epiphytotic conditions. Weighted percentages of economic resistance of tomato varieties to *Fusarium lycopersici* were calculated on the basis of time and severity of appearance of wilt symptoms. Tomato varieties are recorded in the numerical order of their percentages of wilt resistance, beginning with the least resistant. Varieties 19 to 44 per cent resistant were: Stone, Columbia (Haven), Norton, Greater Baltimore, Nystate, and Tomato 1111. Varieties 45 to 69 per cent resistant were: Gulf State Market, Globe, Marvelosa (Vaughan), Gulf State 20–5, Clarks Special B, Break O'Day Urbana Forcing, Lloyd Forcing, Marvelosa (Porte), Early Baltimore, Pritchard, Louisiana Pink ×

Walter Richard, Grothens Red Globe, Marvana (Haven), Long Calyx Forcing, Illinois Pride, Columbia (Porte), Prairiana, Kanora (Barteldes), and Marhio. Varieties 70 to 91 per cent resistant were: Sureset Forcing, Michigan State, Marglobe, Rutgers, Guba's Crosses 421 and 424, Marvel, Blair Forcing, Louisiana Red, Kanora (Melchers), Buckeye State, Marvana (Porte), Marglobe 75, Norduke, Louisiana Pink, and Marglobe 63. Twelve selections of Gulf State Market tomatoes were 34 to 64 per cent resistant. X-ray treatment increased resistance of Marglobe in 1936.

Further Work on Purification of Tobacco Mosaic Virus. CARL G. VINSON. Active virus material in quantity has been obtained by others by employing ammonium sulphate in salting out the virus. The use of a nitrogenous salt in salting out the virus is obviously undesirable. The virus fraction may be precipitated from large quantities of juice from diseased plants by careful acidification. The precipitated virus fraction is readily redispersed by suspending in M/3 phosphate solution of about pH 7.0. Solid, anhydrous sodium sulphate may be used to force the virus out from the phosphate solution in definite crystalline form. Dilute acetic acid may be used to wash the crystals almost free of ash. Shaking the crystalline product with diethyl ether concentrates the pigment on the films. Thus, a practically snow white product is obtained.

Apple-tree Measles. H. C. YOUNG and H. F. WINTER. Measles, as here considered, relates primarily to the pimply and necrotic condition of the inner bark typical of Red Delicious apple trees. After several years' study it was concluded that the disease is non-parasitic. The large number of isolations remained sterile. Grafting, injections of juice from diseased twigs, and budding, using buds from diseased trees, all, failed to produce the disease. Mineral-deficiency studies were next tried. Using Shive's complete nutrient R_3S_3 at one-half atmospheric concentration in purified sand cultures, 7 series of 4 Red Delicious trees, each, were grown for 2 seasons. Series 1 was fed the nutrient solution and the remaining series were given, in addition, 1 and 2 p.p.m. boron, zinc, and manganese, respectively. During the first season fairly normal growth occurred in series 1, whereas the boron-fed trees made about twice the normal growth. A slight toxicity occurred in the zinc and manganese series. After 30 days of the second season, pimples began to appear generally except where boron was used. As the season advanced the inner bark of the trees showed a typical necrotic condition of measles, as it appears in the orchard. Pimply trees, fed on boron, cleared up.

GALL DEVELOPMENT ON PINUS SYLVESTRIS ATTACKED BY THE WOODGATE PERIDERMIUM, AND MORPHOLOGY OF THE PARASITE[1]

R. P. TRUE[2]

(Accepted for publication Aug. 26, 1937)

INTRODUCTION

A *Peridermium* attacks Scotch pine, *Pinus sylvestris* L., plantations bordering Round Lake near Woodgate, New York, causing susceptible trees to form globoid galls. Since its discovery there by York (13) in 1925, it has been called the Woodgate rust or the Woodgate *Peridermium*. York's observations led him to believe that the rust has been present since 1895 in these plantations, some of which, planted in 1870, are among the oldest in America. Some trees of *P. sylvestris* do not form galls after natural infection or inoculation with the fungus. Hutchinson (6) has recently investigated this problem of resistance. The present study deals with the reactions of susceptible trees and the morphology of the rust fungus.

INOCULATIONS AND FIELD NOTES

One hundred forty field inoculations were made upon 27 trees of *Pinus sylvestris*, ranging in age from 9 to 30 years and located in the infection area, supplemented the naturally infected material available for study. The inoculated trees varied widely in susceptibility, as indicated by the varying number of galls they bore from natural infection. The inoculations were made between the 7th and 30th of June from 1930 through 1933. Susceptibility was found to be highest during the first half of June and to decline toward the end of the month.

The aecial inoculum was obtained from fruiting galls collected in the vicinity. Spores for immediate use were carefully removed from the galls as soon as the latter were collected. Galls whose spores were to be used in later inoculations were placed indoors in a dry shaded place and the viability of the spores was tested periodically by placing samples of the spores on fresh well water and noting their percentage germination. Inside storage was resorted to because the spores of galls left late in the field often are blown away or washed out, or they germinate in the aecium.

The method of inoculation was that employed by York,[3] using the cellu-

[1] A dissertation submitted to the Graduate School of the University of Pennsylvania in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Botany.

[2] The writer is indebted to Dr. H. H. York for his advice and criticism during the progress of this work, and to Dr. Conway Zirkle and Dr. K. D. Doak for many helpful suggestions. He also wishes to acknowledge the aid of the Division of Forest Pathology of the Bureau of Plant Industry of the United States Department of Agriculture. The photographs were made with the help of Mr. Vernon Doney with the exception of figure 1, C, which is from one of Dr. H. H. York's negatives.

[3] York, H. H. Celluloid "iceless refrigerator" and some results from field inoculations with the aeciospores of Woodgate rust (*Peridermium* sp.). [Manuscript.]

loid iceless refrigerator. Early inoculations were made upon the stems of the current season's shoots at the time when their elongation separated the developing needles sufficiently to permit a direct inoculation upon the surface of the stem. The needles borne on the young shoots had elongated to more than half their mature size before the last inoculations were made.

Field observations and collections of artificially and naturally infected materials were made each year. During the summer of 1933, observations were recorded and collections made daily for periods of from 3 to 7 days after inoculation and thereafter at weekly intervals. In other years, after the month of June, the intervals between collections varied from 1 to 2 months until dormancy. Notes and collections also were made in late November and in May to reveal the developmental stages present shortly after entry of the host into the winter condition and its breaking dormancy.

ANATOMICAL STUDIES

Methods

Newly inoculated shoots, developmental stages, and mature galls were fixed in the field. Bouin's solution, formal-acetic-alcohol, and formalin-alcohol proved the most satisfactory of the 13 fixatives tried. The first and the last gave the best fixations of the fungus. During fixation, air was removed from the tissues by placing the vials containing the specimens in a closed chamber and evacuating it with a suction pump.

After 12 to 48, and, in some cases, 72 hours of fixation, most of the material was dehydrated and transferred into pure hard paraffin by Zirkle's (14) butyl-alcohol method. Tissues not imbedded at once were stored in the dehydrating mixture made up of 30 parts of water and 50 to 20 parts of ethyl and butyl alcohol, respectively, where they remained reasonably soft until dehydration could be completed.

Early infection and developmental stages for histological study as well as three-year old galls were cut from 8 to 15 μ thick. Material with sori in the bark was cut as thin as 3 μ. Land's method, using a saturated solution of gum arabic followed by a 1 per cent potassium dichromate solution to float out the ribbons, was found most satisfactory in fixing the sections to the slide.

The stains that most clearly differentiated the mycelium in its relation to the host tissue were Orseillin BB in a 3 per cent aqueous solution of acetic acid, counterstained with a similarly acidulated aqueous solution of anilin blue, or with a saturated solution of crystal violet dissolved in clove oil. By following a procedure recommended by Doak,[4] crystal violet in clove oil was used alone to show excellent detail in hyphae and haustoria, but it often necessitated destaining the host tissues too far to show them clearly. The combination of Heidenhain's haematoxylin and iron alum was used to show nuclear phenomena and, in combination with safranin, to show the histological details of the gall.

[4] Personal communication.

For field study, the following rapid method was used to obtain permanent slides: Fresh material was cut in water on a portable sliding microtome and placed at once in Bouin's fixative, where it remained for 10 minutes. It was then washed in water until no further color of the fixative came from it and set to stain for five minutes in Orseillin BB. Excess stain was washed out in the early steps of dehydration and, after a brief clearing, in clove oil followed by xylol, the material was mounted in balsam. The whole schedule may be completed in from 30 to 45 minutes.

External Morphology of Gall Development

In order to make it easier to follow the sequence of internal events described under histological studies, it seems desirable to give a brief summary of the external phenomena that often follow infection and accompany gall development, as observed in inoculated material and supplemented by observations of galls resulting from natural infection. While the phenomena here considered often occur as described, gall formation is very variable and the times and sequence of events show such variation that this brief outline must be considered only as an aid to the understanding of the histological phenomena involved.

Infection occurs primarily through the epidermis of the current season's shoots. Points of infection often are marked by spots that usually range from orange to dark brown. These sometimes appear in the first week of July. Their margins are often sharply defined, but frequently are less definite, and may appear water-soaked. Infection spots do not necessarily indicate successful invasions. Infections whose spots show indefinite or water-soaked margins seem more apt to produce galls than those with more sharply delimited spots. As observed, slight swellings may result in the season of infection below many infection spots and spot-free points of infection. In the second season, dead shrunken cortical areas may appear in the central portion of the surfaces of the swellings, which by the end of that season may become distinct spherical or hemispherical galls. In May of the third season, two years after infection, slight colorless exudates are at times found near the margins of the sunken areas, which, in some cases, may be associated with internal pycnia. Toward the end of the third season, the central sunken area occupies most of the gall surface, and is bounded by a slightly raised rim.

During the fourth season the gall usually acquires those external characteristics which typify it during its further enlargement (Fig. 1, A). Aecia are produced in the central sunken areas of the roughly spherical or hemispherical galls (Fig. 1, D). As the aecia develop, they push up the dead tissues, which usually scale off, eventually exposing the often confluent fruiting surface (Fig. 1, C). Since the layer of aecia-bearing tissue is in turn usually exfoliated before winter (Fig. 1, E), the central portion becomes more and more sunken in comparison with the peripheral rim, which then appears as a collar delimiting the gall (Fig. 1, A, C, and E). On an occa-

sional tree, the periderms of the galls are not sloughed off but, as swelling continues, are cleft by deep cracks in which the aecia may be borne. (Fig. 1, F.)

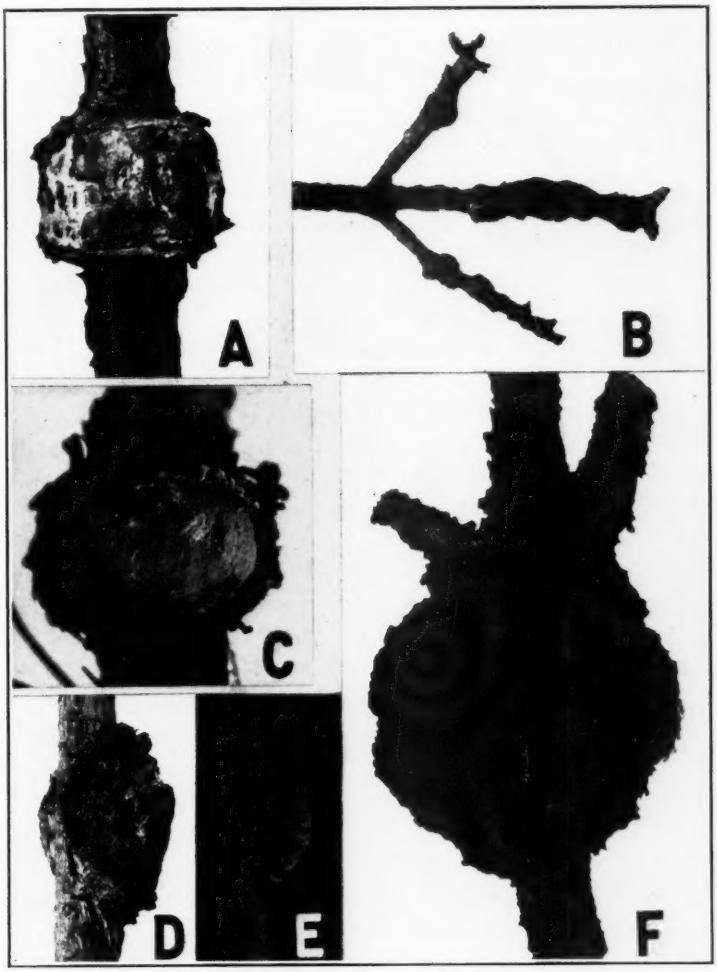

FIG. 1. A. Typical spherical gall with sporulation well advanced. B. Young fusiform swellings due to multiple infections. C. Gall with sporulation completed. Note complete exfoliation of periderm external to aecial layer. D. Hemispherical gall. E. Gall with aecial layer being sloughed away by a new periderm formed benath. F. Ribbed gall with adhering periderm.

Galls on an occasional tree become necrotic and frequently develop abortively, or are misshapen, often through necrosis originating in their central areas, which then appear much more deep-sunken than in normal galls. Such necroses may well at times be caused by invading secondary fungi. Mass infections resulting from inoculations of twigs of highly susceptible trees may cause an extensive killing of the outer layers, which, with subsequent swelling, crack deeply into the woody tissues forming longitudinally

confluent furrowed swellings. These sometimes fail to produce galls or develop into roughly fusiform compound galls (Fig. 1, B), which fruit very sparsely, if at all.

Histology of Invasion and Host Reaction

Epidermis and Primary Cortex. Most successful infection occurs preceding periderm formation. During this period the stem is protected by an epidermis whose outer walls are, in general, heavily lignified and are covered with a thick cuticle (Pl. I, 1). At the bases of needle fascicles, however, walls of the epidermal cells are uniformly thick, apparently uniformly lignified throughout, and usually are pitted. At the fascicle bases, the outer walls of even the subepidermal cell layer become lignified and sunken stomata appear. The cells of the first subepidermal layer are large and radially elongate (Pl. I, 1). Other nonspecialized cells of the cortex appear to be typical of parenchyma tissues in general. Cells of the resin ducts found in the inner cortex are vertically elongate and often contain tannin-like substances, as do a few lignified cells with pitted walls, which are scattered through the cortical parenchyma. About the middle of June a meristem arises from the subepidermal cells or from the cell layers beneath, forming 2 or 3 rows of thin-wall, tangentially elongate cells, the phellogen, external to which the cells die and gradually collapse (Pl. III, 7).

All infections, observed histologically, have been made through the epidermis, either inter- or, more frequently, intracellularly, in the less lignified portions. Appressoria have not been noted. (Fig. 3, D). The germ tube penetrating the cuticle and outer walls of the epidermal cells is considerably narrowed, but, once inside, it broadens, forming a vesicle, and may branch before leaving the cell to enter the subepidermal intercellular space (Fig. 3, A). In the cases of cells penetrated by germ tubes, the thickening of the outer walls was at times much less pronounced than in unpenetrated neighboring epidermal cells. This seems not to be a matter of selection by the fungus, since no unpenetrated walls of comparable thinness were found in the same or similar material. If it is a result of fungus invasion, whether of actual dissolution of the wall or of preventing its normal thickening, it is produced quickly, since it is already obvious in material only 16 days after inoculation. Once the infecting hypha passes from the epidermal cell into the intercellular space below, it branches readily and sends hyphae into neighboring epidermal and subepidermal cells. These hyphae appear to function as haustoria, but, unlike the typical haustoria formed deeper in the cortex, they are often septate and may even branch (Fig. 3, B). This tendency toward intracellular development is short-lived, and the mycelium soon establishes itself intercellularly with typical haustoria.

While trees upon which galls develop are here considered susceptible, a large percentage of the infections fail to result in gall formation, even on the most susceptible trees. Histological studies of early stages of the invasion of such trees have shown that, while some infections meet with no apparent

FIG. 2. A. An invasion resisted partially by cell hypertrophy as at A. B. An invasion spreading vertically along the resin canal (A) has stimulated the adjacent tissues to cell division and radial cell orientation accompanied by marked reduction of intercellular space. C. An invasion being effectively walled out by a cicatrizing zone. D. Radial longitudinal section of infected phloem and xylem. Note broad rays with abundant intercellular hyphae (A); short, blunt irregularly pitted tracheids (B); abundance of phloem parenchyma (C); and resin-containing cavity (D) associated with radial resin canal not shown in this section. E. Transverse section showing wedge-shape area of gall wood with adnormalities intensified at the edge. Note also the internal and external areas of killing in the cortex. F. Longitudinal section showing a late stage in the development of the "collar" with living tissues considerably isolated radially by the death of cells interior to them.

resistance, others are constantly opposed by partial barriers, and yet others may at once be surrounded by barrier zones and walled out completely. In the course of the present study, a shoot no more than 2 cm. long, sectioned serially a month after inoculation, was found to have 24 infections. Five of these showed no trace of recognizable mycelium among the very abnormal

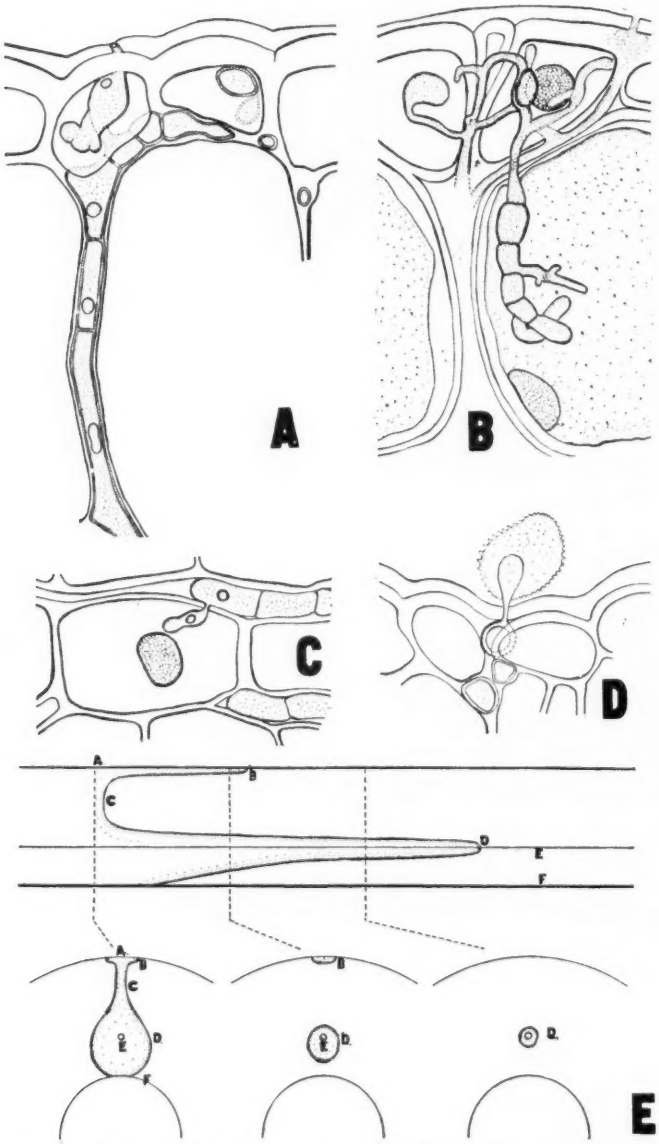

FIG. 3. A. Usual intracellular type of penetration showing vesicle in epidermal cell and subsequent intercellular development. B. Branching septate haustorium within a subepidermal cell. C. Mycelium and haustorium in the phloem parenchyma. D. Spore with short germ tube entering host, showing absence of appressorium and the intercellular type of penetration. E. Diagrammatic representation of the spread of the mycelium of a typical unresisted infection through the primary cortex. Radial longitudinal spread is shown and the appearance of transverse sections taken at various levels is indicated: A, point of penetration; B, extent of subepidermal spread; C, path of radial growth; D, extent of spread adjacent to resin duct in inner cortex; E, cortical resin duct; F, the phloem.

and often dying cortical cells. Most of them showed isolated groups of living hyphae penetrating the more normal portions of the cortex and the intercellular remains of others where tissue abnormalities were more severe. In the case of one infection, discovered in sectioning, where no external symptom was present, the abundant and continuous spread of the large intercellular mycelium had produced almost no abnormality in the areas it penetrated. This infection had penetrated as deeply into the cortex as most of the others, some of which were still confined to the outer cortex.

Infections to which little or no resistance apparently is offered are those that cause but slight early abnormality in the host. The abundant large hyphae pass between or encircle nearly every cell in the infected area (Pl. I, 2 and 3), and many cells are penetrated by the ellipsoid to cylindric haustoria, which are uninucleate and greatly attenuated where they pass through the cell wall (Fig. 3, C and Fig. 6, E). The haustoria often appear to seek out the nucleus of the host cell and those touching it appear at times to be flattened at the point of contact. The host cells in the infected zone are more spherical and regular in outline than those in the normal cortex, and there is a tendency toward hypertrophy, which is most pronounced in the cells invaded by haustoria.

The hyphae of a mycelium whose invasion apparently is unresisted advance in characteristically different directions (Fig. 3, E). Some run parallel to the axis of the twig in the spaces between the first one or two cortical cell layers or just beneath the epidermis. The major portion of the mycelium, however, spreads radially inward through the outer cortex until the inner cortex is reached, and there a second vertical spread occurs, which is most pronounced in the intercellular spaces adjacent to and near the epithelial cells of the resin ducts. These cells often show a tendency to hypertrophy, increasing in size until they may partially or completely fill the ducts. (Pl. I, 2). The mycelium often spreads a considerable distance about the margin of the phloem before entering it. (Pl. I, 3).

Fresh shoots of the current season's growth, collected September 20, 1933, and tested microchemically, indicated a possible physiological explanation for the diversified paths followed by the mycelium in unresisted infections. The layer of cells just below the phellogen, and at times the cells of the phellogen itself, well established at that date, were found containing starch, particularly near the bases of the needle fascicles, where every cell was filled with it. Elsewhere in these peripheral tissues starch was less abundant, appearing only in scattered cells. Internal to this layer the cells of the outer cortex seldom showed starch except below needle fascicles where starch-containing cells are few and scattered. The inner primary cortex, however, had numerous scattered starch-containing cells in the vicinity of the phloem and near the resin ducts. Droplets of fatty substances were present in scattered cortical cells, but were especially abundant in the cells surrounding the resin ducts. Compounds giving a positive reaction to the ferric chloride test for tannins were found in scattered cells in the inner cortex, but especially in the

cells bordering the resin ducts, where they appeared as coarsely to finely granular and, at times, even as amorphous material.

The presence of these substances, at least two of which may be associated with nutrition, in those tissues where the growth of the mycelium is most rapid, suggests that the localization of foodstuffs within the host may influence the paths of invasion in the cases of unresisted infections.

Partially resisted invasions tend to follow the same paths as those whose progress is unopposed, but they meet with localized mechanical resistance from the host, which often alters the direction and curtails the extent of their spread.

Three mechancial responses offer some degree of resistance to the invading mycelium. The first is exaggerated hypertrophy of the cells invaded and often a less pronounced enlargement of contiguous cells (Fig. 2, A). This diminishes the space between the cells, opposing the intercellular proliferation of the mycelium. Close-pressed hyphae in varying stages of abnormality have been observed wedged between the walls of enlarged cells in areas of severe cell hypertrophy. In other cases the advancing hyphal tips may grow beyond the enlarging cells before the extreme stages of hypertrophy are attained and so escape this means of mechanical resistance. The difference in degree of hypertrophy in the invaded host cells seems to be one measure of the compatibility of the reacting organisms.

A second structural response usually offers some resistance to invasion and, like excessive cell enlargement, seems to indicate considerable incompatibility between the host and the invading mycelium. Mature cortical cells in and near the infection area divide, filling the space they formerly occupied with a larger number of smaller cells often oriented in rows radiating from the infected area (Fig. 2, B). The radial arrangement of the cells might appear to favor a swift invasion, but it usually is accompanied by the almost complete elimination of intercellular space, which again appears to be the morphological barrier to further invasion. Both hypertrophic and hyperplastic reactions appear to be direct responses to the invading fungus.

The host often responds structurally to invasion in a third way. A row of phellogen cells derived from mature elements of the primary cortex produces a distinct zone of cicatrization next to infections in which host cells have been killed. This layer cuts off the dead cells, together with some of the very abnormal cells adjacent to them, from the more normal tissues. This cicatrix often serves as a successful barrier against further invasion but does so only when the host cells attacked die so swiftly that the cicatrizing zone walls out the invading mycelium before it has had time to spread (Fig. 2, C). In case of an infection by a mycelium fairly compatible with the host, invaded areas remain nearly normal for some time after invasion during which the invading mycelium spreads deep into the host tissue before any of the invaded cells die, stimulating cicatrization (Pl. II, 2).

Microchemical tests made upon material showing partially resisted inva-

sions revealed that abnormalities in the visible cell contents appear in tissues before they show the structural deviations described above. Starch is unusually abundant in the early stages of physiological abnormality. It is present in large quantities in the morphologically normal cells at the margin of the infection, both before and after the tissue has been invaded and its cells penetrated by haustoria. The presence of these large deposits of starch within and adjacent to the infected areas is accompanied by a scarcity of it elsewhere in tissues in which it normally occurs. Fatty globular substances appear abnormally abundant in the pathic living cells and seem abnormally scarce in adjacent uninvaded tissues. Tannin or tannin-like substances are universally found in cells that have passed the early stages of abnormality; and their appearance often is synchronized with the complete disappearance of starch and fatty substances from the pathic cells. They appear in the wall or lumen of nearly every dead cell.

In the case of barrier formation, the thin-wall cells of the barrier are not cutinized nor lignified, nor do they contain starch, fatty substances, tannin, or tannin-like compounds. They give a negative reaction to tests with Scarlet R; but Hutchinson (6), using ammoniacal gentian violet as a reagent, found them to be suberized in the material with which he worked. A globular fatty metabolite, staining pink with Scarlet R, is often present in the meristematic cells below the barrier, and scattered cells of the adjacent cortex, and starch grains appear similarly distributed.

Whether the invasion is resisted or not, invaded cortical tissues eventually die. Their death occurs generally in the same chronological order as their invasion, so that, in cases of at least moderate compatibility, an external area of killing appears close beneath the epidermis to correspond with the early vertical spread of the mycelium there, and a similar but more extensive internal area is located in the inner cortex, where the internal vertical proliferation took place. These are united opposite the point of epidermal penetration by a smaller area of killing in the outer cortex, where the centripetal spread occurred. (Fig. 3, E).

External areas of killing usually involve the epidermal cells, as well as those directly interior to them, and are clearly visible to the naked eye as infection spots. When these spots are minute or have sharply defined margins, it may be taken as an indication that the invasion is being at least partially opposed by the host; particularly, if they appear within a month or six weeks after inoculation. Larger spots having indefinite margins often appearing water-soaked are likely to mark successful infections, and especially so if their appearance is considerably delayed. In cases of extreme compatibility, swellings may appear before their infection spots. Most infection spots on susceptible trees at Woodgate show intermediate characters.

Peripheral and longitudinal spread of the fungus is limited, at first, almost entirely to the primary cortex, and, later, to the phloem. The mycelium spreads more swiftly in the inner than in the outer cortex, and the death of the invaded cells of the former cuts off the partially invaded and

mostly living cells of the latter from radially conducted water and nutrients. (Pl. I, 4). Thus isolated, they in turn die and collapse against the dead inner cortex, forming a sunken area at the surface of the central portion of the swelling. The peripheral areas of the outer cortex, only partially, or not at all so isolated, remain alive for some time as a rim or collar. This becomes more pronounced after the middle or the end of the second season when the infected cambium usually has cut off considerable phloem tissue, which serves thereafter in the place of the cortex as the chief region of vertical and peripheral spread of the mycelium. In the third season, on fruiting, the dead tissues of the central sunken area are sloughed away, making the collar even more prominent (Fig. 2, F). In the enlarging gall this collar gradually dies back as its edges are further isolated by the continual dying of the tissues internal to it, but it remains distinctly prominent in the case of most mature galls, even after several years.

While responses of resistance often fail to prevent gall formation on susceptible trees, they may so limit peripheral spread of the organism that a hemispherical rather than a spherical gall is produced (Fig. 1, D), or they may hold the mycelium in the cortical region for one or more seasons, thus delaying gall formation. The mycelium of an unresisted infection was noted penetrating the cambium on July 20 of the season of infection and, by August 1, the hyphae of several of that season's infections, some of which had been resisted, had penetrated beyond the cambium. One case was noted in which a resisted infection was just entering the phloem on June 15 of the season following that of its epidermal penetration.

Matured Stelar Tissues. The mycelium passes through the intercellular spaces of stelar tissue derived from uninvaded cambium largely in a radial direction. The structural response of the cells of phloem tissue to the presence of the fungus is limited mostly to cell enlargement, but a division of some of the matured cells at right angles to the line of invasion, and even the formation of a barrier, have been observed in exceptional cases. Penetrating mostly along the phloem rays, the mycelium crosses the cambium at right angles and continues its radial path mostly along the medullary rays for but a short distance into the xylem, where it fails to cause any appreciable structural abnormalities.

Like the cortex, however, the stelar tissues may undergo a marked physiologic response because of the presence or even the proximity of the fungus. Starch grains and fatty droplets, present to some degree in the normal parenchymatous cells of both phloem and xylem, are often present there in abnormally large amounts in tissues adjacent to, as well as within, infected areas.

Cambium. While the fungus usually causes but slight structural abnormality in the matured phloem and apparently none in the xylem, its presence stimulates the cambium to the production of definite and characteristic abnormalities in the phloem and xylem formed after cambial invasion. In view of Bailey's (3) work, indicating that the length and volume of tracheids of normal gymnosperms are closely correlated with the length and volume

of their cambial initials, it seems likely that these abnormalities reflect abnormalities in the cambial initials induced by the presence of the fungus in the cambium.

The cambium usually is first penetrated at a point or over a limited area adjacent to the point of infection, and subsequent cambium invasion comes always from the phloem, never from vertical or peripheral spread of the mycelium within the cambium itself (Pl. II, 4 and 5, and Pl. III, 6). Since the cambium is stimulated rather than killed by the invasion, normal and invaded portions are found functioning side by side and producing normal and abnormal phloem and xylem adjacent to each other (Pl. II, 1). Newly invaded cambium, *i.e.*, that at the edges of the invaded areas, produces phloem and xylem cells showing greater abnormality than those at the center of the areas that have been invaded for some time. This fact, together with the relatively slow rate of invasion of the adjacent normal cambium areas, often results in the formation of a more or less wedge-shape body of gall wood whose edges show greater abnormalities than its center (Fig. 2, E).

Among the abnormalities found in tissues derived from invaded cambium are the following:

1. Increase in radial and tangential diameter of both phloem and xylem elements. In the case of the xylem this often is accompanied by a pronounced shortening of the tracheids, which are often blunt (Fig. 2, D, Pl. II, 4 and Pl. III, 6).

2. An 80 to 100 per cent increase may be shown in the number of xylem cells formed. No comparable increase is shown in the number of phloem elements.

3. Increase in the proportion and number of parenchymatous cells in both phloem and xylem. In the phloem these almost completely replace the sieve tubes (Pl. II, 1), while, in the xylem, the number of parenchymatous cells associated with the resin ducts is so increased that often continuous areas of parenchymatous cells extend from one duct to another, particularly in the areas at the edges of the abnormal wood.

4. Increase in the number of vertical resin ducts in the xylem. This increase, however, is roughly in proportion to the increase in the volume of gall wood, and, though their diameters are abnormally large, many of them are partly or entirely closed through the swelling of their epithelial cells (Pl. II, 5).

5. Frequent production of radial resin passages in the fusiform rays of the phloem, which terminate next to the cortex in resin-containing cavities, somewhat spherical as seen in transverse and in radial longitudinal sections. These have been observed very seldom in normal wood (Fig. 2, D, and Pl. II, 3).

6. Increase in the number, height, width, and cell volume of linear rays in both phloem and xylem. (Fig. 2, D; Pl. III, 4 and 5). The number of xylem rays may be increased by 50 to 60 per cent, as seen in cross section. While the height of normal xylem rays is from 1 to 5 cells and the rays are

comparatively widely separated vertically, abnormal rays vary from 2 to 6 cells high and often appear almost vertically confluent one with another as seen in tangential longitudinal sections (Pl. III, 4 and 5). Width of normal linear rays of the xylem is 1 and very exceptionally 2 cells, while those in the gall wood vary from 1 to 3 and even 4 cells. The much greater volume of the cells in abnormal wood increases the significance of the discrepancies indicated above.

7. Increase in size and number of the fusiform rays comparable to that noted for linear rays.

8. The radial rows of xylem and phloem lose something of their orderly appearance as seen in cross sections (Pl. II, 1), a phenomenon noted in a lesser degree in normal wood making fast growth.

9. Pitting of the tracheids is found on the tangential as well as the radial walls (Pl. III, 5) to which it is considered limited in normal wood of *Pinus sylvestris* (10).

10. Cell walls of abnormal tracheids vary in width but often are twice that of the normal. Walls of the elements produced at the end of the growing season do not differ appreciably in thickness from those of the spring wood and the diameter of the cells is much the same throughout the annual ring, so that these rings are often difficult to distinguish in gall wood.

Discussion of Anatomical Studies

Meinecke (8) and Klebahn (7) have shown that repeating pine rusts may reinfect their pine hosts through the young epidermis of the current season's shoots. In the present study, as in the work of Hutchinson (6), the actual penetration of the epidermis by aecial germ tubes was observed.

While no detailed histological studies have previously been made of galls formed by the Woodgate *Peridermium*, the galls of *Cronartium quercuum* (Berk.) Miyabe (*C. cerebrum*) have received considerable attention. Weir (12) considered the annual growth of the galls to be stimulated by the presence of the perennial mycelium of the fungus in the living sapwood. Dodge and Adams (4) found the mycelium of *C. quercuum* (*C. cerebrum*) in galls on *Pinus rigida* Mill. to be intercellular and uninucleate, abundant in the cortex and apparently following the rays in the phloem and xylem. Haustoria were constricted where they penetrated the cell wall, were found to be abundant in the rays, common in the phloem, and comparatively scarce in the primary cortex.

Stewart (11) found that many of the tracheids in the gall wood of *C. quercuum* (*C. cerebrum*) had blunt ends and were differentiated from the wood parenchyma cells only in their pitting, which, at times, was irregularly 'Araucarian,' with the bars of Sanio seemingly lacking. The pits varied greatly in size and bordering, even in the same tracheid. Nonfusiform rays were often 2 to 3 cells wide, abnormally abundant, and composed of unusually large cells. Three times the usual number of resin canals appeared in cross

section, often so close that only the ray cells separated them. Above and below the gall, the normal number was present.

The present study has indicated the similarity of the galls produced by the Woodgate *Peridermium* to those of *C. quercuum* (*C. cerebrum*) as described by Stewart. He, however, interpreted the discolored nonconducting core as resinous in nature, while, in the case of the Woodgate *Peridermium*, the discoloration is probably due to tannin derivatives. Resin was found limited to the canals and did not impregnate the wood in any general fashion. It is well to bear in mind, however, that the term "tannins" as used in this paper includes the broad range of substances that give the "tannin" reaction with ferric chloride. Unlike the galls studied by Stewart, those of the *Peridermium* at Woodgate can, and often do, influence the structure of the host beyond them where no mycelium is present. Beyond the gall, the stem is often of larger diameter than below it, probably because of the fact that the abundance of phloem parenchyma in the gall has cut off much of the normal downward passage of elaborated material, which expresses itself in this diameter increase. With this diameter increase goes an increase in the number of resin canals. At times a tendency toward brooming may arise beyond or on the distal portion of the gall.

EFFECT OF GALL DEVELOPMENT UPON CONDUCTION THROUGH THE XYLEM

On August 18, 1933, conduction experiments were made with eosin to determine in some degree the effect of the gall upon the conduction of water

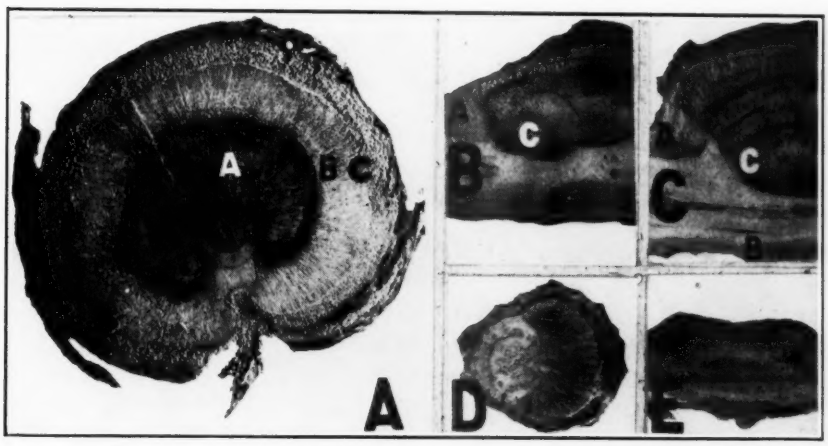

FIG. 4. A. Transverse section through an unstained gall showing dark color of the core (A) and wide area of conducting tissue (B) between it and the cambium at (C). B and C. Longitudinal sections through galls through which eosin has been conducted, staining the conducting tissue as at A and B. Note the contrast between the conducting eosin-stained tissue and the non-conducting naturally discolored core (C) and the nearly complete absence of conducting tissue between the core and the cambium of gall C. The branches beyond A and B appeared normally vigorous while that distal to C was dwarfed and dying. D. Young gall in which whole of gall wood still functioned in conduction and showed the eosin stain. E. Young gall in which the core failed to show the stain as strongly as the outer portion and whose core is inferred to have become at least partially non-conducting, though as yet no natural discoloration had appeared in it.

and dissolved substances to the branch beyond. One-, 2-, and 3-year-old portions of stems, with and without galls, were cut off below the surface of an eosin solution. The galls and noninfected areas of the galled twigs and normal twigs were examined when the eosin reached the tips of the current season's wood, and the stained and unstained areas were noted. In this way the presumably water-conducting wood, stained pink, was differentiated from the nonconducting which remained unstained.

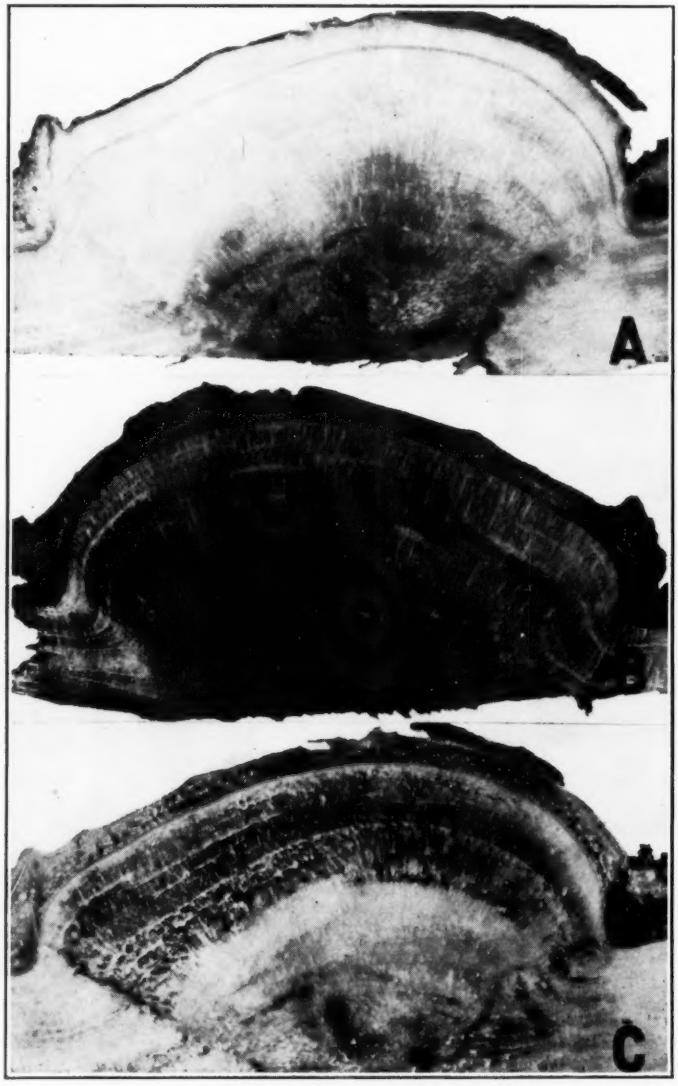

FIG. 5. A. Longitudinal section through untreated gall showing discolored core at center. B. Similar section of gall tested for tannins showing the positive tannin reaction of the core. C. Similar section of gall tested for starches showing the positive starch reaction of the woody tissues external to the core and the absence of starch from the core itself.

While all the gall wood of the 1-year-old swellings was active in conduction (Fig. 4, D), an undyed, or lightly stained, central core often appeared in 2-year-old galls (Fig. 4, E). In some of the 2-year-old and all of the 3-year-old galls, the cells of this nonconducting core were filled with brownish substances (Fig. 4, A). These cells and nondiscolored cells close to them contained tannin-like compounds instead of the starches and oils so abundant in the parenchymatous cells of the major part of the nondiscolored gall wood (Fig. 5, A, B, and C). In three-year-old normal stems, however, the whole woody cylinder was stained, and all the tracheids seemed to have been active in conduction.

The nonconducting discolored core of mature galls may be relatively small (Fig. 4, A and B) or may extend outward from the center of the gall and include all the cells of the gall wood except those most recently derived from the cambium (Fig. 4, C). If the first condition exists, the galls may cause little or no abnormality beyond the areas of local swelling. In the second condition, however, the branch beyond the gall may often be dwarfed or dying.

ASH ANALYSES[5]

In the hope that analyses of the ash of galls and rust-free portions of susceptible trees would perhaps indicate some differentiation between the physiological phenomena of gall formation and normal branch development, analyses were made on December 1, 1933, of fresh material from susceptible trees that was divided into two lots. The first contained galls from 2 to 4 years old, and the second consisted of the rust-free portions of the same branches from which the galls were taken. Bark and wood were taken together in both samples. These lots were ashed and analyzed by the method of H. S. Washington.[6]

TABLE 1.—*Results of ash analyses of 2 and 4-year-old galls and rust-free portions of stems of Pinus sylvestris*[a]

Constituent	Rust-free portions		Galls	
	2 Yrs.	4 Yrs.	2 Yrs.	4 Yrs.
CaO	17.76%	26.39%	18.57%	22.88%
MgO	5.38	7.22	7.25	6.50
K_2O	35.03	28.39	30.62	25.90
Na_2O	4.46	2.64	1.58	4.29
N	0.51	0.31	0.70	0.95
SO_3	5.33	4.10	5.15	7.46
P_2O_5	13.09	10.83	19.68	18.59
SiO_2	15.54	11.28	7.99	6.09
Fe_2O_3	2.92	3.37	2.68	2.72
Al_2O_3	0.53	6.10	5.75	5.34
MnO	0.41	0.03	0.18	0.12
Cl	0.2	trace	0.10	trace
% Ash	1.31	0.65	1.38	0.88

[a] Results reported on the basis of a carbon and CO_2 free ash.

[5] The author wishes gratefully to acknowledge the research grant from the University of Pennsylvania Chapter of Sigma Xi, which enabled him to have the analyses made.

[6] Analyses were made by H. J. Hallowell, consulting chemist, Philadelphia, Pennsylvania.

Table 1 shows some divergences between the ash of the galls and the rust-free wood. The greater amounts of nitrogen, sulphur and phosphorus in the galls can perhaps be correlated with the large quantities of food substances stored in them. The lesser amounts of silicon present in the galls appear to add a chemical reason to the structural basis of the mechanical weakness shown by gall wood. Most of the results, however, show differences whose explanation is at present difficult. Perhaps when the complexities of the physiology of the host-parasite relationship are better understood these figures may appear more significant but here the methods of ash analysis appear to shed little light on the physiological aspects of the problem.

RÉSUMÉ OF THE LIFE CYCLE AND MORPHOLOGY OF THE WOODGATE PERIDERMIUM

The Woodgate *Peridermium* is autoecious and has but 2 known spore forms, pycnia and aeciospores. The pycnia were first found during the course of this study. They were discovered in material collected on May 17, which had been selected to show developmental stages of the gall and, in choosing and fixing the material, the pycnia had been passed over unnoted. Later, other inconspicuous internal pycnia were found in sections of material from several young galls collected in the same season some of which had shown external traces of exudate at the time of collection. The aeciospores reinfect the host directly. They are roundly and irregularly rhomboid with verrucose walls. No germ pores have been observed in the walls of the aeciospores. (Fig. 3, D). They may germinate on water or upon the host in from 12 to 24 hours. The germ tube protrudes often but not always from an apex of the spore and broadens to form a septate branching hypha, which, within the inoculation chamber, may apparently penetrate the host at once or grow luxuriantly over the epidermis for a considerable distance before entering.

In most cases the mycelium vegetates within the host for 2 seasons and in May of its third season may produce pycnia from small hyphal wefts beneath the periderm of the central sunken portion of the gall often near its edge (Pl. III, 3). In late May and early June of the fourth season, approximately 36 months after infection and in successive seasons thereafter, aecia are produced. They arise from larger and denser wefts arising deeper in the tissue than the pycnial wefts and presumably radially interior to them, though the exfoliation of the pycnial weft precedes aecia formation. As the aecial weft develops, the host cells within and adjacent to it are separated widely from each other, but often do not appear to die for sometime, in consequence. The peridial cells of the young aecium push up the periderm and the upper portion of the hyphal weft, which may then disappear entirely or remain partially adherent to the edges of the mature aecium. The peridium varies from 1 to 4 cells in thickness (Fig. 6, A and Pl. III, 1) and stalactiform structures of the nature of the peridium are sometimes found uniting the dome of the peridium with the base of the aecium (Pl. III, 2).

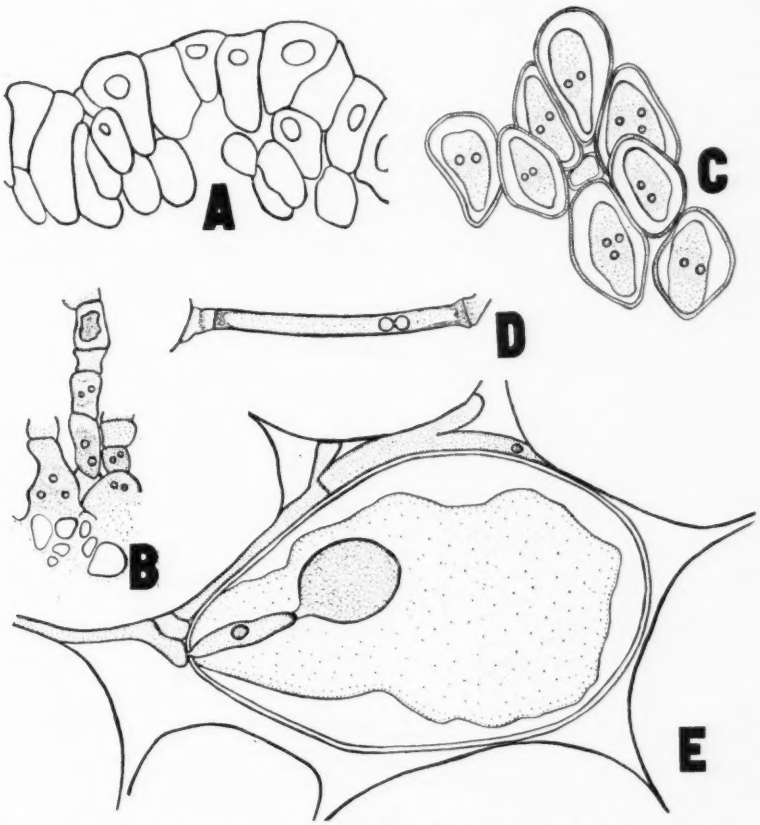

FIG. 6. A. A portion of the dome of the peridium with cells drawn in outline. B. Portion of the bases of aecial spore chains showing binucleate and trinucleate condition. C. Young aeciospores, some binucleate and some trinucleate. D. An apparent binucleate condition in a cell of a vegetative hypha. E. Hyphae and haustorium in the cortex. Note the effects of shrinkage upon the nucleus at its point of contact with the haustorium.

The usual number of nuclei in the vegetative cells and of those making up sterile portions of the wefts is 1, and, while 2 have been exceptionally found in vegetative cells (Fig. 6, D), it seems likely that they do not indicate the initiation of a distinct stage in the life cycle.

A 2-, 3- and, exceptionally, 4-nucleate condition arises in the basal cells of the enlarged hyphae that cut off the young aecial spore chains (Fig. 6, B), and the young aeciospores are in turn usually binucleate but often possess 3 (Fig. 6, C) and at times 4 nuclei. The nuclei in maturing spores apparently become grouped, but no actual fusion has been observed. The young germ tubes, however, often appear to have 2 or more nuclei per cell, but only 1 has been observed in each cell at the time of host penetration. Until further cytological studies can be made upon this organism, the interpretation of these nuclear phenomena would appear hypothetical.

Dodge and Adams (4) found that of a collection of *Cronartium quercuum* (*C. cerebrum*) galls on *Pinus rigida* from New Jersey, some produced only

aecia and others only pycnia per season, and concluded that aecia and pycnia probably were produced on these galls in alternate years. In the case of galls on *P. virginiana* Mill., however, both aecia and pycnia developed on different parts of the same gall in the same year. While galls of repeating western rusts may produce aecia annually, Gill (5) reports that their pycnia are exceedingly rare.

GENERAL DISCUSSION

The Woodgate *Peridermium* is known to be definitely autoecious at Woodgate, New York.[7] The fact that its aecia produce germ tubes that reinfect the host without the production of sporidia precludes the possibility that we have here to do with the microtelia of a typical microcyclic rust. This *Peridermium*, then, in the character of its life cycle, seems only comparable to the two western repeating forms studied by Meinecke (8) and referred to by him as *Cronartium harknessii* Meinecke and *Peridermium cerebroides* Meinecke, and now grouped together by Arthur (2) as forms of *C. coleosporioides* (D. and H.) Arth. and to *P. pini* (Willd.) Kleb., a European repeating pine rust that does not form galls studied by Klebahn (7). The Woodgate *Peridermium* seems, however, to produce pycnia with greater frequency than either of the western forms, and its peridium, 1 to 4 cells in thickness, contrasts markedly with that of the repeating aecial form of *C. coleosporioides* (*C. harknessii*) whose peridium is 5 to 7 cells in thickness (1).

Intracellular penetration was found more frequently than penetration between epidermal cells. The early intracellular development of the mycelium in the epidermis and its formation of atypical, branching, septate haustoria in the subepidermal cells suggest the findings of Pady (9), who has shown the early tendency of infections toward intracellular development to be even more pronounced in the short-cycle orange rust of *Rubus*.

The coincidence of the paths of early, unresisted cortical invasion with the regions more richly supplied with starches and oils seems to signify that there may be a relationship between the amounts of food available to the rust and the supply of demonstrable starches and oils. It is interesting to note that the tannin-like compounds, present in normal quantities in the vacuoles of many cells in these regions, do not interfere with the migration of the mycelium along these paths.

Bearing in mind the possible relationship of potassium to foods available to the rust, Hutchinson (6) considered that resistance varied with the host and found that trees whose ash contained little potassium were more susceptible than those with larger amounts of it. He considered that infections that fail to produce galls in susceptible trees did so primarily through competition and lack of nutriment. In this paper the view is taken that, at Woodgate, susceptibility varies not only with the host but also with the parasite, and that there is a question of compatibility involved between the host and each mycelium whose germ tube penetrates it. It may well be borne in mind, too, that the entrance of secondary organisms, some of which have

[7] H. H. York. The Woodgate *Peridermium*. [Manuscript.]

quite frequently been noted in histological preparations of young galls, might influence the reaction of otherwise compatible hosts.

It is true, as Hutchinson has pointed out, that different parts of the same tree may produce galls more readily than others following infection. The host tissue of a single shoot is a variable factor, since portions of the young stem, such as areas at the needle bases, may be better supplied with starches, oils, etc., than others. Yet it seems unlikely that a commandeering of the food supply by the first mycelium to penetrate could explain the wide variation of host reaction to the different invading mycelia in inoculated twigs where the infections may be considered to have taken place at about the same time. In these cases, too, as in others studied, there seems to have been no relation between the compatibility of the mycelium with its host and the region of the shoot attacked, though definite regions of abundance and scarcity of demonstrable stored foods do exist in the shoot as indicated. Also, areas invaded by incompatible mycelia and those adjacent to them, rather than being free of demonstrable foods, are abnormally full of starch and oil in the early stages of invasion.

Compatibility in susceptible trees, then, seems to vary not only with the host but with some property of the infecting mycelium. That this variable property is a physiological one seems clear. It appears likewise unlikely that a variation in vigor of the invading mycelium is the sole cause of the variation in the host reaction. Rather, it seems likely that some mycelia are genetically better adapted than others to achieve and maintain the metabolic balance with the host so necessary to obligate parasites. Perhaps the varying number of nuclei in the aeciospores may indicate such an instability in the genetic constitution of the *Peridermium* at Woodgate. The question is here raised whether we do not, then, have in this case of a forest tree rust something comparable to the physiologic races recognized among cereal rusts.

Even in the cases of most complete compatibility, the cells of all the invaded areas except the cambium eventually die and, in contrast to phenomena sometimes exhibited in the cereal rusts, die sooner than cells of comparable but uninvaded tissues. This is true of the invaded cortical tissues as well as of the phloem and xylem. The length of time intervening between invasion and death of the cortical tissues usually measures the compatibility of the reacting organisms and consequent susceptibility of the host, since an infection that reaches the cambium seldom fails to cause gall formation. The more compatible mycelia at first cause but little abnormality in the structure or contents of invaded parenchymatous host tissues, but gradually these become filled with starches and oils and, just previous to death of the cells, unusually large amounts of tannins appear in them in the place of the oils and starches. Where compatibility is less, this series of events follows in swifter succession. Coincident with, or shortly after the appearance of an abnormal abundance of tannins in cortical cells, less compatible mycelia meet the resistance of hypertrophy or of hyperplasia or both and the degree of structural abnormality of the tissues is proportional to the physiological

abnormality expressed in terms of host cell contents. Coincident with the death of the cells in the invaded area, a row of meristematic cells arises to form a cicatrix, which proves to be a barrier to invasion only when death of the cells occurs so quickly after invasion that the mycelium has no time to grow beyond the zone of cicatrization.

Only cambial initials in close proximity to the hyphae are influenced by the presence of the organism to produce abnormal phloem and xylem elements. Parenchymatous cells are produced in much greater proportions than normal and these are soon filled with abnormally large amounts of starches, oils, and, in the case of the phloem parenchyma, tannins. Thus, the parasite appears to cause its host not only to provide it with extra food but also with extra food-containing cells. These abnormalities are most pronounced in tissues derived from newly invaded cambium, and there is some suggestion of a return toward the normal in tissues arising from initials in cambium areas that have been invaded for a year or more. After periods of time, which vary in different mature galls from less than 1 to as much as 3 years after their formation, invaded tracheary xylem elements cease to conduct, the starches and oils are replaced by tannins, some of which seem to be located at the periphery of the cells, the cells die, and the mycelium in the affected area dies with them. When death occurs too soon after cell formation, *i.e.*, too close to the cambium, so that the number of conducting cells is much below normal, the branch beyond the gall often shows dwarfing and may die probably, at least in part, because of water shortage. The distance between the cambium and this nonconducting core may be a further measure of compatibility.

SUMMARY

The life cycle of the Woodgate *Peridermium* has been followed histologically from penetration of the epidermis of the current season's shoot of *Pinus sylvestris* by aecial germ tubes through gall formation to production of pycnia 2 years after penetration and repeated formation of aecia in ensuing seasons.

The wide variety of early response of single susceptible twigs to invasion suggests the existence of more than one physiologic race of the *Peridermium* at Woodgate.

Mycelia causing little early abnormality in the tissues invaded are considered as compatible with the host. These penetrate the cortex more swiftly along characteristic diverging paths found to possess demonstrable nutrients in greater abundance than areas traversed more slowly.

In the case of mycelia extremely incompatible with the hosts, starches, fatty substances, and, finally, tannin-like compounds are rapidly concentrated in cells near the hyphae. Following the deposition of abnormally large quantities of the last, these cells die and the fungus dies with them.

The more compatible mycelia grow out in advance of this killing and succeed in forming galls, but cell hypertrophy, hyperplasia, and barrier formation often hinder their passage through the cortex.

Compatible mycelia invade the matured secondary tissues by the end of

the first season, while others may be delayed. Phloem and xylem are invaded mostly along medullary rays. Stelar tissues, matured before invasion, show comparatively slight structural change, but their parenchymatous cells become abnormally full of starches, fatty substances, and tannins.

The presence of the fungus in the cambium causes the production of abnormal secondary tissues containing a high proportion of parenchymatous cells that become in turn filled with starches, fatty substances, and, finally, tannins. Increase in cell size characterizes both phloem and xylem, while only the latter shows a marked increase in cell number. Irregularities in size, shape, and pitting of the tracheids also are produced.

Portions of the cambium penetrated for the first time produce the most abnormal secondary tissues, so that areas of gall wood are outlined by tissues showing the greatest abnormalities.

Abnormal parenchyma tissues in the xylem at first contain large amounts of starch and fatty substances, which are replaced by tannin-like compounds usually during the third season in the oldest gall wood, which then ceases to conduct. In cases where the nonconducting core occupies nearly all of the xylem, the branch beyond the gall often dies.

Meanwhile, the death of the inner cortex and of the abnormal phloem cells leaves portions of the cortex external to them isolated from radial conduction. These portions die, collapse, and later are exfoliated except at the edges, where, by contrast, they appear as a raised collar.

Early in May 2-year-old galls often bear pycnia hidden directly beneath the periderm below the sunken central area. This is the first report of pycnia for the Woodgate *Peridermium*.

Three-year-old galls often produce confluent aecia from extensive dense mycelial wefts in the sunken area arising slightly below those of the then exfoliated pycnia. Each year the tissues containing the aecial weft are exfoliated by a periderm arising internal to them and the next year aecia are formed below the new periderm.

Ash analyses of 2- and 4-year-old galls and rust-free portions of susceptible trees showed the galls to be significantly lower in silicon and higher in nitrogen, phosphorus, and sulphur. Other discrepancies were slight or difficult to interpret.

Preliminary nuclear studies revealed the perennial vegetative mycelium to be predominantly uninucleate. Two, 3 and occasionally 4 nuclei appear in the cells at the base of the aecial chain, the young aeciospores, and many portions of the germ tubes. The latter, however, are markedly uninucleate when they penetrate the host.

DEPARTMENT OF BOTANY
UNIVERSITY OF PENNSYLVANIA
PHILADELPHIA, PENNSYLVANIA

LITERATURE CITED

1. ARTHUR, J. C. The plant rusts. . . . 446 pp. John Wiley & Sons, Inc., New York; Chapman & Hall, Ltd., London. 1929.

2. ARTHUR, J. C. Manual of the rusts in United States and Canada. 438 pp. The Purdue Research Foundation. Lafayette, Indiana. 1934.
3. BAILEY, I. W. The cambium and its derivative tissues. II. Size variations of cambial initials in gymnosperms and angiosperms. Amer. Jour. Bot. **7**: 355–367. 1920.
4. DODGE, B. O., and J. F. ADAMS. Some observations of the development of *Peridermium cerebrum*. Mem. Torrey Bot. Club (1917) **17**: 253–261. 1918.
5. GILL, L. S. Notes on the pycnial stage of *Peridermium cerebroides*. Mycologia **24**: 403–409. 1932.
6. HUTCHINSON, W. G. Resistance of *Pinus sylvestris* to a gall-forming *Peridermium*. Phytopath. **25**: 819–843. 1935.
7. KLEBAHN, H. *Peridermium pini* (Willd.) Kleb. und seine Übertragung von Kiefer zu Kiefer. Flora [Jena] (n. F. 11–12) **111–112**: 194–207. 1918.
8. MEINECKE, E. P. Experiments with repeating pine rusts. Phytopath. **19**: 327–342. 1929.
9. PADY, S. M. Aeciospore infection in *Gymnoconia interstitialis* by penetration of the cuticle. Phytopath. **25**: 453–472. 1935.
10. PENHALLOW, D. P. A manual of the North American gymnosperms. . . . 374 pp. Ginn and Co., Boston. 1907.
11. STEWART, A. Notes on the anatomy of *Peridermium* galls. I. Amer. Jour. Bot. **3**: 12–22. 1916.
12. WEIR, J. R. Observations on the pathology of the jack pine. U. S. Dept. Agr. Bull. 212. 1915.
13. YORK, H. H. A *Peridermium* new to the Northeastern United States. Science (n. s.) **64**: 500–501. 1926.
14. ZIRKLE, C. The use of N-butyl alcohol in dehydrating woody tissue for paraffin embedding. Science (n. s.) **71**: 103–104. 1930.

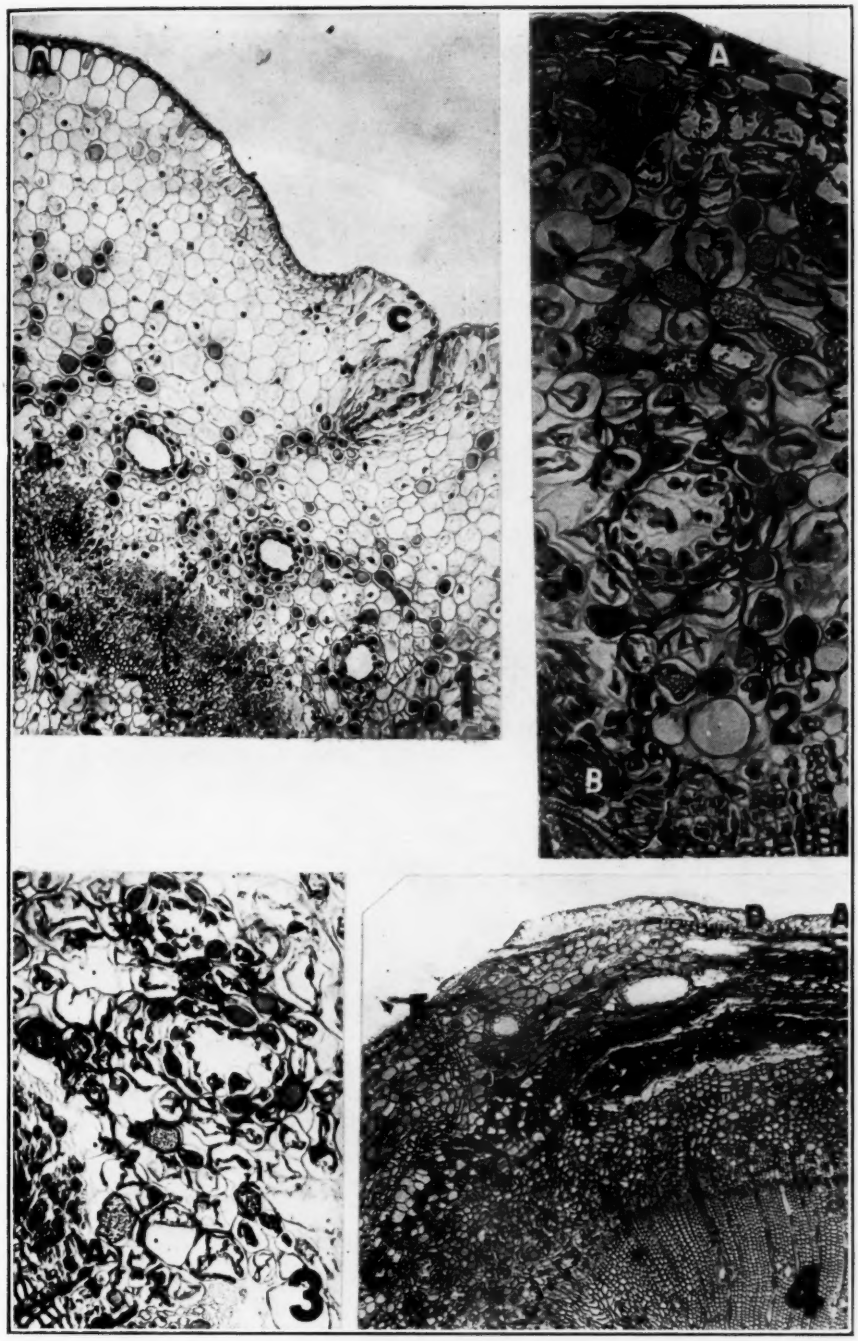

PLATE I

1. Transverse section of a normal twig of *P. sylvestris* as it appears in early June. Note especially the thickness of the walls of epidermal and subepidermal cells at A, the base of the needle fascicle supplied by the bundle trace at B as contrasted with the thinner walls elsewhere as at C. 2–3. Transverse sections showing unresisted invasions. 2. shows a very limited necrosis at point of penetration (A), scarcity of hyphae in the outer cortical region as compared with the inner, especially in the vicinity of the resin canal and the closing of the canal by the hypertrophy of the epithelial cells. The mycelium is shown entering the stelar tissues through a bundle trace at B. 3 shows a resin canal still open in spite of the abundance of hyphae near-by. The mycelium enters the phloem of the main stele at A. 4. Early stage in the formation of the "collar". Necrosis has spread from near the center of infection (A) largely in the inner cortex to B and this, together with pronounced abnormalities arising in the inner cortex and phloem from B to C, has partially isolated the outer cortex external to it. Following its isolation, it has become severely necrotic from A to D and appears to be dying also from D to E where a barrier from D to C is forming to separate the dying portion from the more normal cortex at the left in the photograph.

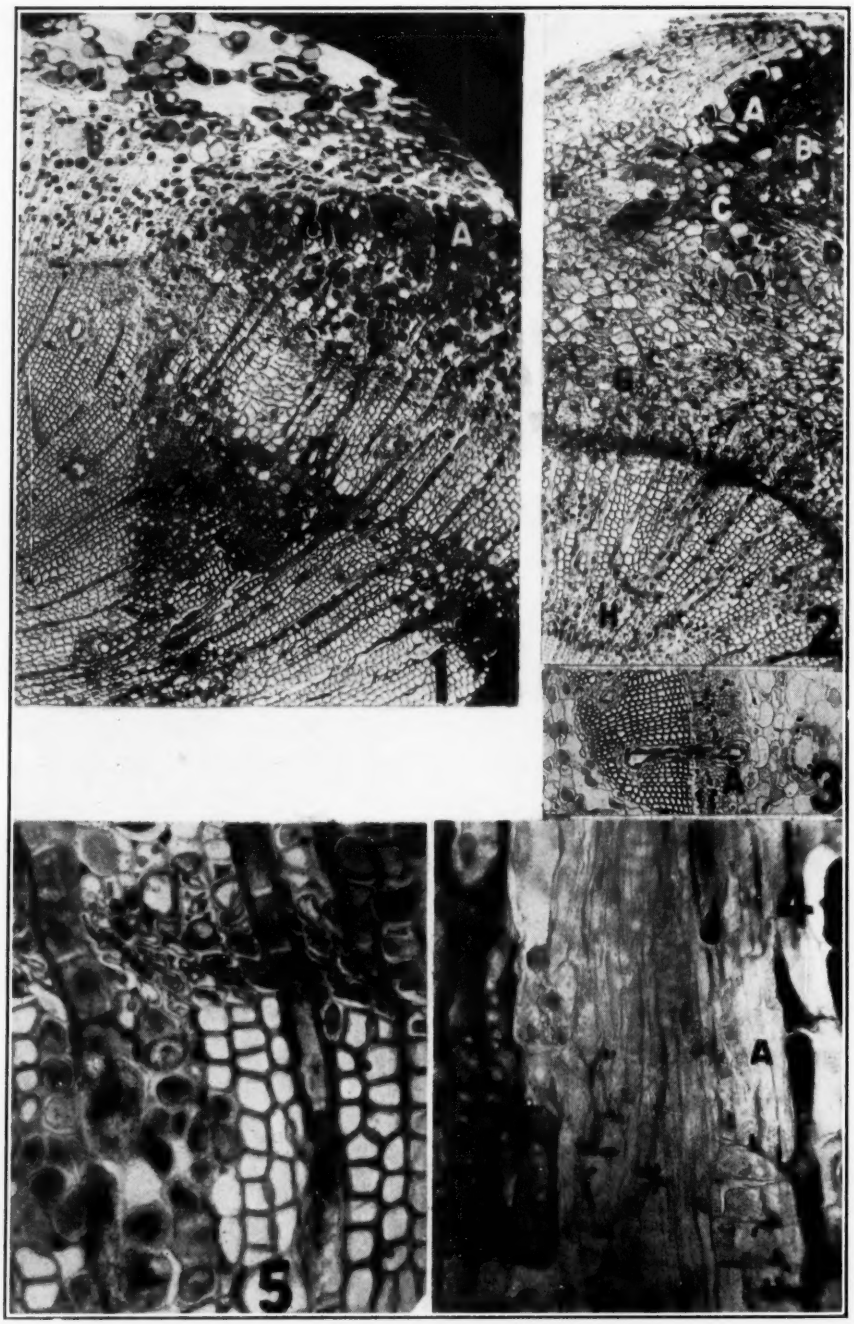

PLATE II

1. Transverse section showing the edge of an infection with invaded and uninvaded secondary tissues side by side. Note that in the pathic phloem the parenchyma cells with their deeply staining contents (A) have almost completely displaced the sieve tubes (B), which comprise most of the phloem in uninvaded tissues. 2. A cicatrizing zone formed from A to B to C to D has proved ineffectual in resisting the invasion as has the similar zone from A to E to F, which formed later. Note that the mycelium is already present in the phloem G and xylem H. Radial resin duct in uninvaded tissue uniting the resin cavity A in the phloem with the vertical xylem resin duct. 4. Radial longitudinal section showing edge of infection where the mycelium is advancing vertically and radially into uninvaded phloem (A) and crossing the cambium to enter the very abnormal xylem. Note that abnormalities in the secondary tissues are produced at some distance in advance of the mycelium. 5. Transverse section showing mycelium crossing the cambium and distributed mostly radially in pathic phloem and xylem though not always confined to the rays.

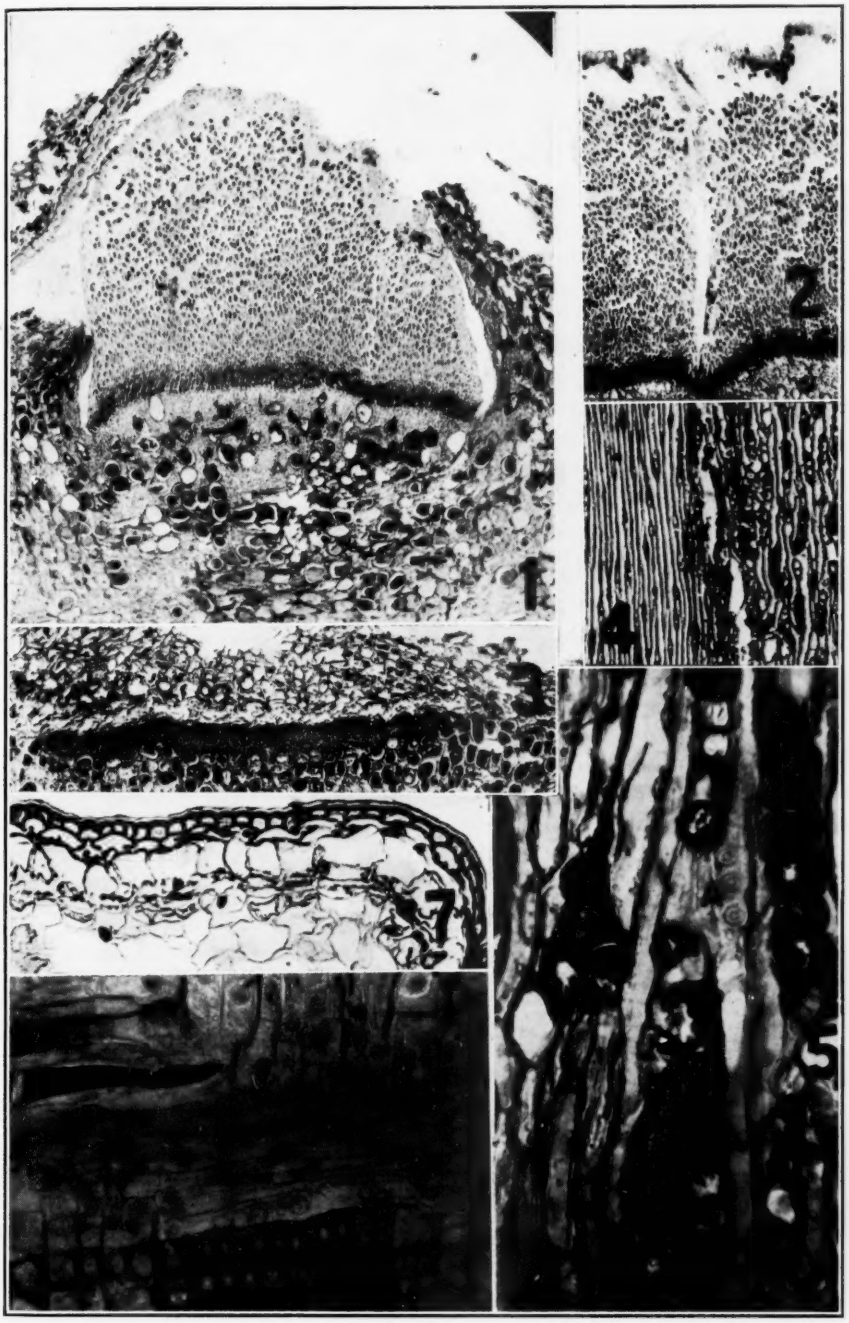

PLATE III

1. Section through a small aecium showing external periderm, the peridium of the aecium, the darkly stained basal cells of the spore chains, and the widely separated host cells below the aecium. 2. Section through the filaments occasionally found showing their double character and suggesting that they are separations between otherwise confluent aecia. 3. Section through a pycnium showing the very limited pycnial weft and its position below the periderm. 4. An approximately tangential section through gall wood and uninvaded wood adjacent showing the irregularities and large size of the cells of the gall wood and their disproportionately large amount of parenchymatous tissue. 5. A higher magnification of a portion of the gall wood shown in 4, showing particularly the tangential pitting of one of the walls of one of the tracheids at A. 6. Radial longitudinal section showing the mycelium oriented radially in and near the cambium. 7. Epidermis and periderm of normal *P. sylvestris* as they appear in early August.

FAILURE OF DASYSCYPHA WILLKOMMII AND RELATED LARGE-SPORE SPECIES TO PARASITIZE DOUGLAS FIR

GLENN GARDNER HAHN AND THEODORE T. AYERS

(Accepted for publication September 23, 1937)

INTRODUCTION

Soon after the discovery of the European larch canker, in 1927, in Massachusetts (8), Douglas firs, *Pseudotsuga taxifolia* (LaM.) Britt., growing adjacent to the diseased European larches, *Larix europaea* D. C., were reported as being attacked by this introduced European disease. The basis of this report was the finding on cankered Douglas fir, of a large-spore *Dasyscypha,* which at the time appeared to agree with available descriptions of the larch canker fungus. This parasite had been reported in European literature as attacking Douglas fir (5, p. 900).

There was also present on the Douglas fir canker, a related *Dasyscypha,* the identity of which, and its relationship to the European larch canker organism, was uncertain at the time. In a separate investigation, this unidentified *Dasyscypha* was found to be a native species, *D. ellisiana* (Rehm) Sacc., commonly present as a saprophyte on species of pine in the east. Artificial inoculations, on which a preliminary report has been published (5), have demonstrated that this native *Dasyscypha* in some cases is capable of acting as a weak parasite and of causing canker of Douglas fir. The investigation has shown, however, that *D. ellisiana* is not entirely responsible for the diseased condition of Douglas fir in New England.

To determine whether Douglas fir would be attacked by the true larch canker organism, *Dasyscypha willkommii* (Hartig) Rehm, and related large-spore species (4), namely, *D. calycina* Fckl., introduced from Europe, and the native species, *D. oblongospora* Hahn and Ayers and *D. occidentalis* Hahn and Ayers, inoculations were made with these organisms on this conifer at different times from 1931 to 1934. The inoculations were supplemented by a field search for the larch-canker fungus on Douglas fir, not only in the area where it was discovered on imported larch (8), but also in other localities in New England. Previous to this study in the United States, unfruitful search for the larch-canker fungus had been made in Great Britain on Douglas fir growing in pure plantations and in mixed plantings with European larch. In Britain, larch canker has been present many years and is found attacking larches growing intermixed with Douglas fir.

The results obtained from these studies have a direct bearing on the planting of Douglas fir in the United States and in European countries where the larch canker is established and widespread. Moreover, general statements recently published by us (5, p. 901) concerning the failure of the European larch-canker organism to parasitize Douglas fir under American conditions, are substantiated by detailed experimental and observational evidence described in this paper.

FIELD SEARCH FOR DASYSCYPHA WILLKOMMII ON DOUGLAS FIR

In Europe

A brief, preliminary field study of planted Douglas fir in Scotland with regard to possible infection by the European-larch-canker organism was made by the senior author in 1928 and 1929. These observations were confined to plantations at Glentress above the town of Peebles, in the Valley of the River Tweed, Peeblesshire. At an elevation of 400–500 feet there were small plantations of Douglas fir, both green and blue forms, varying in age up to approximately 20 years.

One of these consisted of a mixture of the green form with Norway spruce and European larch in which the European-larch canker was causing severe injury to the latter species. The moist conditions prevalent in this stand, which was closely crowded, were particularly favorable for the propagation of the larch-canker fungus and related Dasyscyphae, which were fruiting abundantly on larch. Such a situation proved to be an excellent one in which to search for *Dasyscypha willkommii* on rapidly growing, dominant, and stunted, suppressed green Douglas fir, among which the D. B. H. varied from 3–7 inches.

After careful search among several hundred trees, in no instance was a single Dasyscypha canker on the Douglas fir found resembling those so commonly present among the diseased European larch. However, infrequently, a very few, small, inconspicuous fruit cups of *Dasyscypha*, resembling macroscopically the European-larch-canker organism, were found growing on weakened, suppressed, lower branches which were either dead or in the process of dying. Later, a microscopic and cultural study of this *Dasyscypha* species, found to occur saprophytically on larch as well as on Douglas fir, showed it to be distinct from that parasite. As in the case of European-larch-canker organism, this *Dasyscypha* produced large elliptical spores, but these were not pointed as in the case of some of the ascospores of *D. willkommii*. This Douglas fir Dasyscypha, which might be confused by some with the true larch- canker fungus because of its large elliptical spores, has been referred (4) to the species *D. calycina* (not *Peziza calycina* Schum.).

Furthermore, an examination of a blue Douglas fir plantation, in which some of the green form was growing not far distant from the mixed stand just described, did not reveal Dasyscypha cankers nor fruiting of the fungus. The vigor of trees of the blue form had been reduced by *Rhabdocline pseudotsugae* Syd., which was prevalent and causing a serious needle cast.

Another young plantation[1] of trees of the green form, planted in 1923

[1] Baxter, D. V. Observations on forest pathology as a part of forestry in Europe. Michigan Univ. School of Forestry and Conserv. Bull. 2. 1933. There is a photograph of this plantation in Pl. IV, fig. 1. Baxter does not report the occurrence of *Dasyscypha* on Douglas fir in this planting. In Pl. VIII he shows badly deformed and cankered trunks of European larch caused by *Dasyscypha willkommii*, growing in an open stand near Peebles. This plantation adjoined the mixed one of larch, spruce, and Douglas fir referred to in the foregoing. Note the stunted green Douglas fir in the foreground.

(about 8 years old) in the same general area, had suffered seriously from frost injury that had killed back the terminals, giving the trees a stunted appearance. This plantation was, likewise, free of larch-canker organism. In this instance 2 species of *Phomopsis* following frost killing, *Phomopsis occulta* Trav. and *P. conorum* (Sacc.) Died., were identified by the senior writer as being commonly present.

It is of interest here to note that Boyce (1), who made a survey of the diseases of Douglas fir in Great Britain in 1925, also visited and made studies in the Peeblesshire area just described. He did not report the European-larch-canker organism as either a parasite or a saprophyte on *Pseudotsuga taxifolia.*

The senior writer's experience in searching for the European-larch-canker fungus on Douglas fir in Scotland corroborates that of Plassmann (7) in Germany, who, likewise, sought for the larch parasite on that species. In that country, where larch canker in the past has been a serious disease and where Douglas fir has been planted, Plassmann was unable to find *Dasyscypha willkommii* acting either as a parasite or a saprophyte on that conifer, although the tree species was frequently grown in close association with diseased larch, making the spread of spores of *D. willkommii* to the Douglas fir extremely easy. In his reply to the controversial question, "*Dasyscypha willkommii*—a new disease of the Douglas fir?" which was discussed by Trendelenburg (9) in a report to German foresters, Plassmann (7) stated that on the basis of his field experience in Germany the larch-canker organism was not to be feared as an enemy of the introduced forest tree.

In England, on the other hand, Day has collected what he regards as the larch-canker organism [which he called *Dasyscypha calycina* (Schum.) Fckl.] on Douglas fir as well as Scotch pine. Day submitted collections of these Dasyscyphae to Plassmann, who confirmed his determinations, but expressed the further opinion that "In beiden Fällen, und das muss hier ausdrücklich hervorgehoben werden, ist *Dasyscypha willkommii* aber reiner Saprophyt" (7, p. 367). In connection with the *Dasyscypha* collections made by Day on Douglas fir in England, which we have not seen and, therefore, have been unable to compare with our specimens collected on Douglas fir in Scotland and the United States, it is of interest here to note that he does not report the larch-canker organism among the secondary fungi associated with Douglas fir cankers commonly resulting from frost damage (2). This type of lesion would appear to the writers to be a very likely sort of place for the occurrence of a *Dasyscypha* form acting in no way as a parasite. On the other hand, Day (3) states in a later paper that the larch-canker fungus was present in the dead tissues of all the larch cankers of traumatic origin that he studied.

In the United States

An intensive search was begun in the autumn of 1929 for large-spore species of Dasyscyphae among the diseased trees of Douglas fir (6) growing adja-

cent to infected imported European larch at Hamilton, Massachusetts, where the 2 species had been growing together undisturbed for approximately 20 years. The great abundance of fruit bodies of *Dasyscypha willkommii*, which occurred on the larch in this particular area where diseased trees had not yet been removed, gave evidence that the European disease was on the point of becoming a serious outbreak.[2] Inasmuch as the site on which both European larch and Douglas fir were growing was highly favorable to the propagation of larch canker and the organism fruiting on the lesions, it was reasonable to expect that infection could have extended readily to the Douglas fir if this conifer had been susceptible.

A search in this plantation of Douglas fir from 1929 to 1933, which period included eradication of the adjacent diseased larches in 1932 and 1933, did not reveal fruit bodies of *Dasyscypha willkommii*. Moreover, the writers failed to find the larch-canker organism in other diseased Douglas fir plantations in New England some distance removed from the larch-canker infection area. Although there has been ample opportunity for Douglas fir to become infected during the time the larch canker was undisturbed, and before eradication had been undertaken, there is no evidence that the causal organism is able to attack species other than those of the genus *Larix* and its close relative, golden larch, *Pseudolarix amabilis* Rehder (5).

INOCULATION EXPERIMENTS

In order to learn whether the European larch-canker fungus, *Dasyscypha willkommi*, and 3 closely related large-spore Dasyscyphae, would infect Douglas fir, 143 artificial inoculation tests were performed with these fungi. The inoculations were made in the late summer and autumn of 1931, in the spring of 1932, in the winter of 1933 and in the spring of 1934, under controlled conditions in recently planted (1930) 8-year-old transplant stock of the Colorado or blue form of Douglas fir. Healthy, vigorous trees were utilized as well as some that were languishing and dying and some practically dead. The inocula used were derived from recently isolated cultures of the Dasyscyphae, procured from single asci or asco-spores growing on 3 per cent malt agar. The isolations of the larch parasite were obtained from collections taken in the infection area at Hamilton, Massachusetts. In a few inoculations, freshly collected fruiting bodies of the larch-canker organism itself were employed, together with bits of the diseased tissue of larch upon which they were growing.

The following technique was employed. The place to be inoculated was first cleansed with a cotton swab soaked in 95 per cent ethyl alcohol to remove débris clinging to the uninjured back. This was followed by a final alcohol wash for sterilization purposes. Incisions were made with a sterile scalpel by slitting the bark parallel to the long axis of the trunk or branch and gently raising the bark from the wood on both sides of the slit with the sharp

[2] Spaulding, P., C. B. Bidwell, J. S. Boyce, and A. W. Gottlieb. Report of committee on forest disease control. 3 pp. Presented at meeting New England section, Soc. Amer. Foresters, Boston, 1936. [Mimeographed.]

tip of the incision instrument. The entire incision was approximately 1 cm. long. The inoculum was then inserted into this with a sterilized needle, and the cut edges pressed down gently so that the wound was not only almost closed, but also the severed tissues were brought into direct contact with the inoculum. Finally the wound was wrapped tightly with a bit of cotton soaked in sterile distilled water, and the whole tied up in an outer wrapping of waxed paper that served both to conserve moisture and to aid the inoculating fungus in gaining a foothold for its initial growth on the injured tissues. Checks were made in a similar manner except in this instance only sterile agar was used.

A series of 18 Douglas fir trees were used for these tests, 6 of which were inoculated with 2 or more *Dasyscypha* species. In table 1 are given various details of the inoculations of current to 5-year-old wood of *Pseudotsuga taxifolia* with the 4 large-spore species of *Dasyscypha*. The places of inoculation were the trunk, main shoot, branch, or axil of a lateral branch and main axis. Checks were similarly placed but on wood that was 3 to 6 years old. Since none of the fungi were able to cause cankers, detailed reports of the individual inoculations do not seem justified.

In table 1, a total of 54 inoculations are reported for *Dasyscypha willkommii*, 35 of which were made with malt agar cultures and the remaining 19 with freshly collected apothecia of the larch-canker fungus growing on dis-

FIG. 1. Apothecia of *Dasyscypha calycina* Fckl. produced by a mono-ascus strain inoculated on dying Douglas fir. *A*. The arrow indicates the incision about which artificially produced ascocarps were produced. *B*. Enlargement of fruit bodies about the incision indicated in *A*. Approx. × 1.5.

eased larch tissue. Seven of these were made in a weakened tree and the remainder on 2 vigorous trees. In none of the inoculations was there any evidence that *D. willkommii* was parasitic or *saprophytic* on living or dead tissue of Douglas fir.

In the case of the *Dasyscypha calycina* inoculations, only agar cultures were used. As shown in table 1, 17 of these inoculations were made on healthy trees while 35 were placed on dying or dead trees. In only one instance, a mono-ascus strain of this species showed ability to colonize 6 incisions made August 13, 1931, on a single weakened Douglas fir, the needles of which were still green at the time of its inoculation, but the tree was not

TABLE 1.—*Inoculations of Douglas fir with Dasyscypha willkommii and related species*

Species of *Dasyscypha* and tree condition	Inoculation dates	Strains tested	Trees tested	Inoculated incisions	Cankers	Incisions colonized	Non-inoculated incisions	Cankers on non-inoculated incisions
D. willkommii:	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Vigorous	7	6	7	39	0	0	25	0
Weak	2	1	1	15	0	0	3	0
Total	9	7	8	54	0	0	28	0
D. calycina:								
Vigorous	4	4	4	17	0	0	13	0
Dying	4	5	5	23	0	6	6	0
Dead	1	1	2	12	0	0	6	0
Total	9	10	11[a]	52	0	6	25[b]	0
D. oblongospora:								
Vigorous	2	2	2	11	0	0	6	0
Dying	4	5	5	13	0	5	6	0
Total	6	7	7[a]	24	0	5	12[b]	0
D. occidentalis:								
Vigorous	2	2	2	7	0	0	6	0
Dying	3	3	4	6	0	0	3	0
Total	5	5	6[a]	13	0	0	9[b]	0

[a] A total of 18 Douglas fir trees were inoculated. Several of the trees were inoculated with the different fungus species: 3 trees in the *Dasyscypha calycina* tests were used for *D. willkommii;* 6 trees in the *D. oblongospora* tests were used for *D. willkommii* and *D. calycina;* 5 trees in the *D. occidentalis* tests were used for the other 3 species.

[b] A total of 56 check incisions were made. Eighteen of these checks served for more than one species of *Dasyscypha* inoculated on the same tree at the same time.

making new growth. The inoculum used in this particular case was obtained originally from a meager collection of *D. calycina* (F. P. 53056),[3] growing saprophytically on dead, noncankered branches of Douglas fir growing adjacent to diseased European larch at Hamilton, Massachusetts. *Dasyscypha calycina* gained a foothold in the dying tissue, and, after 2 years, colonies of the fungus had formed, producing small but normal fruit bodies on the underside of the branch, opposite the incision slit (Fig. 1, *B*) or in its immediate vicinity. These artificially produced apothecia did not extend more than 1.5 cm. above or below the incision, probably because of the fact that the

[3] Collection numbers denote specimens for study filed in the Division of Forest Pathology, B. P. I., New Haven, Conn.

Douglas fir tissues had become dried out (Fig. 1, *A*); and with this change in moisture relationship further spread of the fungus was inhibited.

The morphological characters of the artificially produced apothecia of *Dasyscypha calycina* were identical with those of fruit bodies of the fungus produced naturally on Douglas fir and larch in the larch-canker infection area. These characters have been described and figured in our paper (4) in which *D. willkommii* and *D. calycina* have been presented as separate species. In Britain, certain workers, as pointed out by Boyce (1, p. 12), regard these 2 species as members of a polymorphic species. They have recognized that the forms differ physiologically, but not morphologically.

A total of 37 inoculations were made with agar cultures of the native species, *Dasyscypha oblongospora* and *D. occidentalis*. In the case of the former, strains of *D. oblongospora* (53185), isolated from apothecia collected on Douglas fir in the Hamilton infection area, were able to colonize 5 out of 6 incisions made September 24, 1931, on a single dying tree of Douglas fir, which possessed green needles but had ceased putting on new growth. Three of the incisions were inoculated with a mono-ascus strain and three with a mono-ascospore strain. As in the case of *D. calycina* described above, normal apothecia formed within a period of two years from the time of inoculation with the mono-ascus strain. However, in the case of the other 3 inoculations with the mono-ascospore strain, 1 of which was negative, stromata of the fungus developed on the tissue about the incisions. In one instance, however, there appeared among the stromata a single fruit body that up to the time of examination, had not formed asci.

The morphological characters of the fertile, artificially produced apothecia of *Dasyscypha oblongospora*, as in the case of *D. calycina* discussed above, were likewise identical with those of fruit bodies occurring naturally on tamarack and other conifers. In both instances the experimentally produced ascospores were germinable, and the cultures obtained from them showed close agreement with those obtained from naturally produced ascospores of these 2 species. The fact that the morphological characters of artificially produced fruit bodies were similar to those of naturally produced ascocarps, indicated that the characters we had designated as descriptive of the species *calycina* and *oblongospora* (4) were constant for these species.

In our inoculation experiments, *Dasyscypha occidentalis*, which resembles rather closely *D. calycina*, failed to grow either parasitically or saprophytically on Douglas fir. The results of these tests corroborate our field observations, since this fungus has never been found on that conifer in either northeastern or western United States. In the Pacific Northwest, *D. occidentalis* is especially abundant on western larch, *Larix occidentalis* Nutt., growing in mixed stands with Douglas fir, but it never has been found on the latter species. In contrast, *D. oblongospora* (4), which is commonly saprophytic on larches and pine in eastern United States, has been collected a few times on Douglas fir in New England.

Although only a limited number of inoculations were made, we have been successful in demonstrating the colonization by *D. calycina* and *D. oblongo-*

spora of dying Douglas fir tissue. When one considers how rarely we found these species occurring naturally on similar tissue of that conifer, the results obtained are quite understandable. Furthermore, even though our experiments have not been very extensive to support the statement that *D. willkommii* will not colonize artificially weakened and dying Douglas fir tissue, field observations described in the preceding section have demonstrated that very probably this does not take place. Inasmuch as *D. willkommii* did not manifest saprophytism under natural conditions favoring such an occurrence, it does not seem very probable that we would have been successful in an artificial attempt.

SUMMARY

Artificial inoculations, supported by field observations, indicate that, in the United States, the European-larch-canker parasite, *Dasyscypha willkommii* (Hart.) Rehm, does not grow on the blue form of Douglas fir, either parasitically or saprophytically. Furthermore, the writers have found no evidence that this organism parasitizes Douglas fir in Europe.

Closely related saprophytes, the introduced *Dasyscypha calycina* Fckl. (not *Peziza calycina* Schum.) and the native *D. oblongospora* Hahn and Ayers, have been found fruiting rarely on the dead branches of Douglas fir in the area where *D. willkommii* was discovered on imported European larch and where Douglas fir was growing adjacent to the cankered larches. These 2 saprophytes were induced to grow upon the dying tissue of Douglas fir, but not upon living healthy tissue.

The morphological characters of artificially produced apothecia of *Dasyscypha calycina* and *D. oblongospora* were identical with those described for apothecia of these species produced naturally.

Another member of the large-spore group, the native *Dasyscypha occidentalis* Hahn and Ayers, has not been found growing either saprophytically or parasitically on Douglas fir, in nature or in the inoculations.

DIVISION OF FOREST PATHOLOGY
BUREAU OF PLANT INDUSTRY
IN COOPERATION WITH OSBORN BOTANICAL LABORATORY
YALE UNIVERSITY, NEW HAVEN, CONN.

LITERATURE CITED

1. BOYCE, J. S. Observations on forest pathology in Great Britain and Denmark. Phytopath. **17**: 1–18. 1927.
2. DAY, W. R. Damage by late frost on Douglas fir, Sitka spruce, and other conifers. Forestry **2**: 19–30. 1928.
3. ———. The relationship between frost damage and larch canker. Forestry **5**: 41–56. 1931.
4. HAHN, G. G., and T. T. AYERS. Dasyscyphae on conifers in North America. I. The large-spored, white-excipled species. Mycologia **26**: 73–101. 1934.
5. ———, and ———. The European larch canker and its relation to certain other cankers of conifers in the United States. Jour. Forestry **34**: 898–908. 1936.
6. HOWARD, N. O. A new disease of Douglas fir. Science (n. s.) **69**: 651–652. 1929.
7. PLASSMANN, E. Eine neue Krankheit der Douglasie? Allg. Forst u. Jagd. Ztg. **106**: 365–368. 1930.
8. SPAULDING, P., and P. V. SIGGERS. The European larch canker in America. Science (n. s.) **66**: 480–481. 1927.
9. TRENDELENBURG, R. Eine neue Krankheit der Douglastanne. Allg. Forst u. Jagd. Ztg. **105**: 233–234. 1929.

TAXONOMIC RELATIONSHIPS OF PLANTS SUSCEPTIBLE TO INFECTION BY TOBACCO-MOSAIC VIRUS

FRANCIS O. HOLMES

(Accepted for publication Oct. 1, 1937)

For many years it was thought that tobacco-mosaic virus (tobacco virus 1) could infect only solanaceous plants. Later 2 susceptible species were recognized in other families. These were *Martynia louisiana* Mill. in the family Martyniaceae (1) and *Phaseolus vulgaris* L. in the family Leguminosae (7). In 1934 Grant (2) presented a radically different view of the situation; he infected 29 of 121 tested species in 14 different families among 40 that he investigated. His recognition of wider susceptibility depended on the use of more effective methods of inoculation than had been available for most earlier studies and on observation of symptoms other than systemic mottling. It seemed to the writer that an even larger proportion of tested species might be found susceptible to infection with strains of tobacco-mosaic virus if other methods of determining susceptibility were used to supplement the usual method of observing symptoms after inoculation.

On this account, 2 auxiliary tests were applied to plants of 73 species of herbaceous dicotyledons. Most, but not all, species were subjected to both tests. One of these tests was dependent on quantitative measurement of virus developed at the site of inoculation, the other was dependent on conspicuous local lesions. In the first test, a green-mottling strain of tobacco-mosaic virus was used; in the second, a yellow-mottling strain of the same virus. To date 63 per cent of the 73 species have proved susceptible. These include some that have long been supposed to be immune.

It is the purpose of this paper to present the data derived from the 2 sets of tests. The observations are not primarily of importance as indicating the wide range of disease caused by tobacco-mosaic virus, since many of the newly demonstrated hosts localize the virus and are little injured by its presence. The results are considered significant rather because they show a close relationship between susceptibility of plants and taxonomic affinities. Perhaps there is a corresponding orderly distribution in nature of some substances or conditions important for increase of tobacco-mosaic virus. The failure of the virus thus far to multiply *in vitro* lends interest to any conceptions with regard to factors allowing or preventing its increase.

MATERIALS AND METHODS

Plants were secured for testing by transplanting a wide variety of dicotyledons found growing as weeds in greenhouses, fields, and woods in the vicinity of Princeton, N. J. Susceptibility tests were performed only on young plants, in a greenhouse held at a temperature of about 22° C. (rarely below 21° C. or above 27° C.). The plants were later grown on maturity for identification of species. Aid in identification was kindly given by members of the staff of The New York Botanical Garden.

The first type of test consisted of quantitative measurement to detect increase of virus at the site of inoculation. For this test all plants were inoculated with typical tobacco-mosaic virus (distorting strain of tobacco-mosaic virus, 4, p. 847; 5, p. 897). Inoculation consisted of rubbing 3 or more leaves of each plant with a cheesecloth pad saturated with expressed juice of mosaic plants of Turkish tobacco (*Nicotiana tabacum* L.), diluted with about 50 parts of water. The rubbed area on the leaves was then further inoculated by making at least 100 pin punctures through the residual inoculum with No. 00 insect pins bound together in a fascicle of 5. Generally, only one plant of each species was tested. The rubbing treatment constituted an inoculation sufficient under the conditions of the tests to produce about 150 primary infections in a comparable leaf area of *N. langsdorffii* Weinm., used as a control on infectivity of inoculum. Pin-puncture inoculation was not thought to be so effective as rubbing inoculation, but it served to mark the inoculated leaves for later identification and furnished a safeguard against the possibility that some species, not susceptible to infection by rubbing, might yet prove susceptible by pin-puncture inoculation.

Ten to 12 days after inoculation, the marked leaves from each plant were separately wrapped in cheesecloth, and crushed. Diluted and undiluted expressed juices from each sample were used to inoculate 5 leaves of a plant of *Nicotiana langsdorffii*. A species was considered susceptible when undiluted juice expressed from inoculated leaves induced the production of more than 10 necrotic primary lesions on the leaves of *N. langsdorffii*. Nearly all the susceptible species produced concentrations of virus sufficient to give far more than this minimum number. A few may have been incorrectly classified by adherence to this arbitrary limit, but it was necessary to use some standard. This seemed a suitable requirement, since experience has shown that residual virus on leaves thus inoculated gives less than this number of lesions. Moreover, of the 3 species giving small but significant numbers of lesions in the subinoculation experiments, 2 showed susceptibility also when the second type of test was applied.

All but 2 of the species not shown to be susceptible by this test for virus increase, together with many of the species known to be susceptible, were subjected to the second type of test. This involved inoculation with a yellow-mottling strain (572 D1) derived recently from the distorting strain of tobacco-mosaic virus. This strain produced yellow-mosaic symptoms in tobacco and in many other susceptible species. The symptoms induced by it have been represented in an earlier paper (5, Fig. 1, a), as typical of those produced by highly invasive yellow-mottling strains of tobacco-mosaic virus. The typical tobacco-mosaic virus used in the first test rarely produced visible local lesions, but the yellow-mottling strain often gave evidence of its increase in the inoculated tissues by production of yellow lesions at the site of inoculation, even in plants in which it did not produce systemic infection. It was necessary to avoid large amounts of virus in the inoculum when typical tobacco-mosaic virus was used, lest residual inoculum interfere with

tests for increase of virus. The yellow-mosaic strain, on the other hand, could be applied without dilution, since no subinoculation test was to be made. Through its use, a few species, judged by the tests for virus increase to be doubtfully susceptible, or insusceptible, were shown to be susceptible.

A large part of this work was completed before the description by Rawlins and Tompkins (8) of their useful method of inoculation with carborundum. A few additional trials were made by this method, but they failed to infect species previously found insusceptible. Future development of better methods for inoculation and for recognizing infection may finally show a larger proportion of species to be capable of supporting increase of tobacco-mosaic virus, but present methods seem to have demonstrated the existence of a naturally insusceptible group.

RESULTS OF EXPERIMENTS

In the accompanying table, the tested species are arranged by families in the order in which they appear in Gray's New Manual of Botany (3). Susceptibility is indicated by the letter S in the 5th column wherever the results of subinoculation tests for virus increase (3rd column) or results of inoculation with the yellow-mottling strain of virus (4th column) justify such a classification. Some of these species were later tested for virus in uninoculated leaves at the tops of the plants. A record of the number of lesions produced by this subinoculation is given with that for the inoculated leaf. It appears after a semicolon and a small letter s, signifying systemic infection. Thus, in the table, *Polygonum hydropiper 550*; *s, 0* indicates a plant with a localized infection; in this species much virus was detected in the inoculated leaf after 10 days, but none in uninoculated leaves at the top of the same plant after a month. On the other hand, *Hedeoma pulegioides 950*; *s, 930* signifies a plant with systemic infection; in this species much virus was detected in juice expressed from each source.

The distribution of susceptible and insusceptible species in the table suggested the existence of 4 natural groups: 1st, a largely susceptible group, from Polygonaceae to Cruciferae, of 9 families, with 22 susceptible and 2 insusceptible species; 2nd, an almost entirely insusceptible group, from Rosaceae to Umbelliferae, of 11 families, with 2 susceptible and 16 insusceptible species; 3rd, an entirely susceptible group, from Verbenaceae to Rubiaceae, of 5 families, with 13 susceptible and no insusceptible species; and 4th, a group only partly susceptible, comprising the families Lobeliaceae and Compositae, with 9 susceptible and 9 insusceptible species.

Consideration of the tested families from the viewpoint of their probable relationships as represented by Mez and Ziegenspeck (6) discloses associations of susceptible species that are still more striking than those shown in the linear arrangement of the table. The Königsberger Stammbaum is an evolutionary diagram, constructed by the aid of serological tests that determine affinities of plant species on the basis of common antigenic constituents. A reduced representation, following the plan of the Königsberg diagram, is shown in figure 1, A. Only families tested in the present study are included;

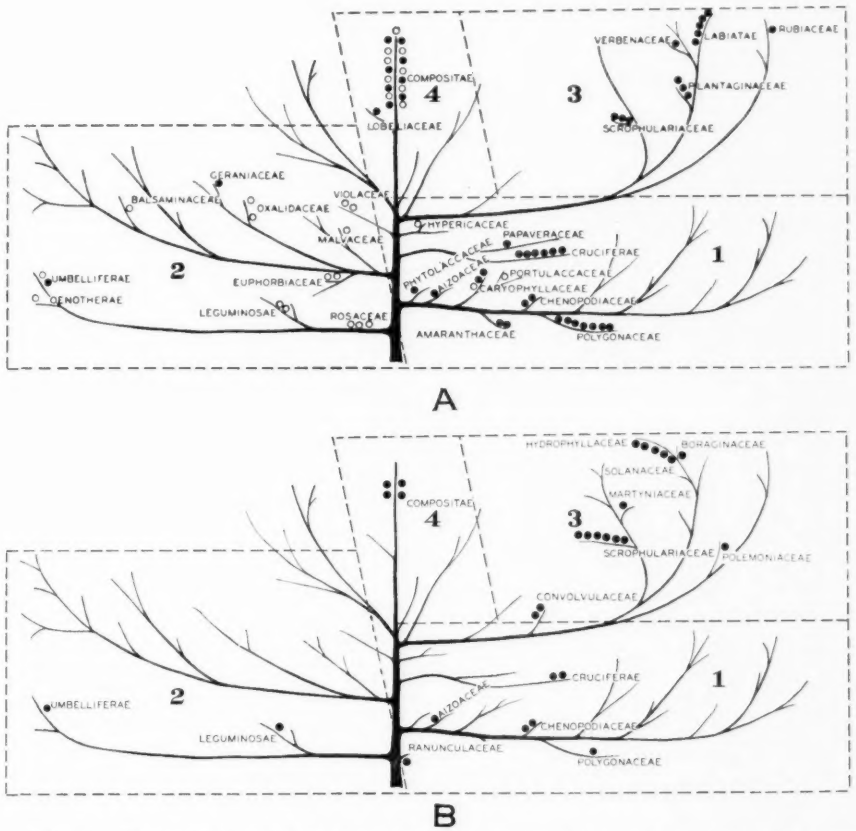

FIG. 1. Taxonomic relationships of plants susceptible to infection by tobacco-mosaic virus. A. Families of tested dicotyledonous plants, diagrammatically arranged according to the plan of the Königsberger Stammbaum of Mez and Ziegenspeck (6). Species tested by inoculation with tobacco-mosaic virus are indicated by circles; black circles indicate susceptible species; white circles, insusceptible species. B. Similar diagram, showing distribution of species found susceptible by Grant in 1934 (2).

species are indicated by circles (black for susceptible, and white for insusceptible species), and the 4 groups are separated by broken lines. The 1st group of families, mentioned previously as consisting largely of susceptible species, comprises 3 branches on the right of the diagram. The 2nd group of families, consisting mostly of insusceptible species, constitutes 3 branches on the left side. The 3rd group of families, comprising only susceptible species, constitutes a single great branch on the right; this branch carries the Solanaceae, not included in this study, but known to contain many susceptible species. The 4th group, of mixed susceptibility, represents the top of the main stem of the diagram. The 4 groups in the table and the corresponding groups in the diagram differ in but one species, *Hypericum boreale* (Britton) Bicknell of the Hypericaceae, which appears in the 2nd group of the table but in group 1 of the diagram.

The diagrammatic representation shows more clearly than the linear arrangement of the table that susceptible species occur almost entirely in

TABLE 1.—*Arrangement of tested species of plants by families, with results of experiments performed for detection of increase of the distorting strain, and for detection of symptoms induced by a yellow-mosaic strain (572 D1) of tobacco-mosaic virus*

Family	Species	Lesions on subinoculation; distorting strain	Symptoms observed yellow-mosaic strain; 572 D1	Susceptibility
Polygonaceae	*Rumex crispus* L.	550	Yellow primary lesions; red peripherally	S
	" *acetosella* L.	350	None	S
	Polygonum aviculare L.	600	Large elongated yellow primary lesions	S
	" *erectum* L.	180	Elongated yellow primary lesions	S
	" *persicaria* L.	290; s, 2	None	S
	" *hydropiper* L.	550; s, 0	None	S
	" *convolvulus* L.	570	Yellow primary lesions, elongated along veins	S
Chenopodiaceae	*Chenopodium ambrosioides* L.	900	Necrotic primary lesions	S
	" *album* L.	250	Small yellow primary lesions, becoming necrotic	S
Amaranthaceae	*Amaranthus hybridus* L.	6	Yellow primary lesions	S
	" *graecizans* L.	31	Yellow primary lesions, becoming semi-necrotic	S
Phytolaccaceae	*Phytolacca decandra* L.	2	Yellow primary lesions on mature leaves only	S
Aizoaceae	*Mollugo verticillata* L.	500	Yellow primary lesions, becoming necrotic	S
Caryophyllaceae	*Stellaria media* (L.) Cyrill.	0	Few yellow primary lesions	S
	Cerastium vulgatum L.	700	Zonate yellow primary lesions, becoming necrotic	S
	Lychnis alba Mill.	5; s, 0	None	...
Portulacaceae	*Portulaca oleracea* L.	0	None	...
Papaveraceae	*Chelidonium majus* L.	570; s, 0	Diffuse yellow primary lesions	S

TABLE 1.—(*Continued*)

TABLE 1.—(*Continued*)

Family	Species	Lesions on subinoculation; distorting strain	Symptoms observed yellow-mosaic strain; semicolor 572 D1	Susceptibility
Cruciferae	*Lepidium ruderale* L.	330; s, 90	Not tested	S
	" *campestre* (L.) R. Br.	740; s, 0	Yellow primary lesions extending down veins	S
	Capsella bursa-pastoris (L.) Medic.	600	Yellow primary lesions	S
	Sisymbrium officinale (L.) Scop.	65	Multizonate yellow primary lesions	S
	" *thalianum* (L.) J. Gay	525	Not tested	S
	Radicula palustris (L.) Moench.	180; s, 0	None	S
Rosaceae	*Potentilla arguta* Pursh	0; s, 0	None	-
	" *monspeliensis* L.	0; s, 0	None	-
	Geum canadense Jacq.	0; s, 0	None	-
Leguminosae	*Trifolium repens* L.	0	None	-
	Medicago sativa L.	4; s, 0	None	-
Oxalidaceae	*Oxalis stricta* L.	0	None	-
	" *corniculatus* L.	0	None	-
Geraniaceae	*Geranium carolinianum* L.	39	Yellow primary lesions and systemic yellow mottling	S
Euphorbiaceae	*Acalypha virginica* L.	3	None	-
	Euphorbia maculata L.	0; s, 0	None	-
Balsaminaceae	*Impatiens biflora* Walt.	9; s, 0	None	-
Malvaceae	*Malva rotundifolia* L.	0; s, 0	None	-
Hypericaceae	*Hypericum boreale* (Britton) Bicknell	0; s, 0	None	-
Violaceae	*Viola papilionacea* Pursh	0	None	-
	" *sagittata* Ait.	0; s, 0	None	-
Onagraceae	*Circaea lutetiana* L.	0; s, 0	None	-
Umbelliferae	*Sanicula canadensis* L.	0	None	-
	Daucus carota L.	450	None	S
Verbenaceae	*Verbena urticaefolia* L.	44; s, 0	None	S
Labiatae	*Prunella vulgaris* L.	275; s, 0	Yellow primary lesions	S
	Lamium amplexicaule L.	450	Yellow primary lesions	S
	Hedeoma pulegioides (L.) Pers.	950; s, 930	Systemic yellow mottling	S
	Lycopus virginicus L.	135	None	S
	" *rubellus* Moench.	86; s, 0	None	S

TABLE 1.—(*Concluded*)

Family	Species	Lesions on subinoculation; distorting strain	Symptoms observed yellow-mosaic strain; 572 D1	Susceptibility
Scrophulariaceae	*Linaria vulgaris* Hill	400	Zonate yellow primary lesions	S
	Veronica officinalis L.	0	Few zonate yellowish green primary lesions	S
	" *peregrina* L.	56	None	S
Plantaginaceae	*Plantago major* L.	400	Necrotic primary lesions	S
	" *rugelii* Dene.	81; s, 0	Yellow primary lesions, becoming necrotic	S
	" *lanceolata* L.	100	Yellow primary lesions, becoming semi-necrotic	S
Rubiaceae	*Galium triflorum* Michx.	19; s, 0	None	S
Lobeliaceae	*Lobelia inflata* L.	65	None	S
Compositae	*Solidago rugosa* Mill.	0; s, 0	None	..
	" *graminifolia* (L.) Salisb.	0; s, 0	None	..
	Aster ericoides L.	0; s, 0	Not tested	..
	" *multiflorus* Ait.	0; s, 0	Not tested	..
	" *lateriflorus* (L.) Britton	0; s, 0	None	..
	" *dumosus* L.	390; s, 0	Not tested	S
	Erigeron annuus (L.) Pers.	255; s, 0	Yellow primary lesions	S
	" *canadensis* L.	1	Yellow lesions, becoming necrotic	S
	Ambrosia artemisiifolia L.	17	Few yellow primary lesions	S
	" *trifida* L.	13; s, 0	Few yellow primary lesions	S
	Rudbeckia hirta L.	0; s, 0	None	..
	Helianthus tuberosus L.	0; s, 0	None	..
	Bidens frondosa L.	430; s, 0	Yellow primary lesions	S
	Galinsoga parviflora Cav.	270	Yellow primary lesions, elongated along veins	S
	Cirsium arvense (L.) Scop.	5; s, 0	None	..
	Taraxacum officinale Weber	1	None	..
	Hieracium scabrum Michx.	0; s, 0	Few yellow primary lesions	S

closely associated families (at the right of the diagram), and that insusceptible species are also definitely grouped together (at the left of the diagram). The Compositae, shown at the top of the diagram, are known to have affinities with families at each side; it is not surprising, therefore, that they show susceptibility in some species and not in others.

To summarize the data presented in table 1 and figure 1, A, it may be stated that 46 of the 73 tested species proved susceptible. One of the 46 species (*Daucus carota* L., wild carrot) has been reported previously as being susceptible (2); Grant infected a cultivated form of this species.

For comparison with the distribution of the 46 species here found susceptible, the 29 non-solanaceous hosts originally reported by Grant (2) are shown in figure 1, B; only 2 of these, *Daucus carota* and *Phaseolus vulgaris*, fall into the 2nd group of families shown in the table and diagram. Grant found all 5 tested species of the Hydrophyllaceae to be susceptible; this family was not represented in the writer's tests, but it, like the largely susceptible family Solanaceae, belongs to the 3rd group, in which all tested species proved susceptible.

DISCUSSION

Substances and conditions requisite for increase of tobacco-mosaic virus are evidently more widespread in herbaceous dicotyledons than has been previously recognized, 63 per cent of the tested species in all families proving susceptible. If the species of plants in the 11 families referred to as constituting the largely insusceptible group 2 are excluded from consideration, 80 per cent of the remaining species are susceptible. If the moderately susceptible group 4 also is eliminated, 95 per cent of the remaining species (35 of 37) are susceptible; these species are distributed in 14 related families. Recognition of so large a proportion of susceptible species as here reported is dependent on the use of 2 tests for virus increase *at the site of inoculation*. Exclusive use of tests for *systemic spread* of virus, including measurement of virus increase and observation of symptoms, permits the recognition of far fewer susceptible species.

Localization of virus within the inoculated leaf was found to be a very common phenomenon among the tested species. It is probable that systemic invasion by tobacco-mosaic virus occurs in only a minority of susceptible species among flowering plants in general.

It is often desirable to obtain virus from pairs of species not closely related to each other, since unrelated hosts are not likely to possess identical antigenic compounds or proteins. If hosts are selected from families in group 3 of the table on the one hand, and from families in groups 1 or 4 on the other hand, numerous pairs of susceptible, but distantly related, plants may be obtained. Some of the chosen species may localize the virus, but objection to their use need not be raised, even though traces of inoculum from the original host plant may be considered undesirable in extracted juice. The difficulty can be avoided by a series of transfers from leaf to

leaf in the new species, to eliminate all previous constituents of the original host plant, except the tobacco-mosaic virus, itself.

SUMMARY

Among 73 tested species of herbaceous dicotyledons, about two thirds (46) proved susceptible to infection with tobacco-mosaic virus. The criteria of susceptibility were detection of increase of virus in inoculated leaves by quantitative subinoculation tests and observation of symptoms at site of inoculation. A correlation seemed to exist between accepted taxonomic classification and susceptibility, since almost all of the tested species in one group of 11 families apparently lacked ability to support increase of tobacco-mosaic virus, whereas 95 per cent of the species in another group of 14 families were shown to have this ability.

FROM THE DEPARTMENT OF ANIMAL AND PLANT PATHOLOGY OF
THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH
PRINCETON, NEW JERSEY

1. FERNOW, K. H. Interspecific transmission of mosaic diseases of plants. [New York] Cornell Agr. Expt. Sta. Mem. 96. 1925.
2. GRANT, T. J. The host range and behavior of the ordinary tobacco-mosaic virus. Phytopath. **24**: 311–336. 1934.
3. GRAY, A. Gray's new manual of botany. . . . Ed. 7, rearr. and extensively rev. by B. L. Robinson and M. L. Fernald. 926 pp. American Book Co., New York, Cincinnati, and Chicago. 1908.
4. HOLMES, F. O. A masked strain of tobacco-mosaic virus. Phytopath. **24**: 845–873. 1934.
5. ————. Comparison of derivatives from distinctive strains of tobacco-mosaic virus. Phytopath. **26**: 896–904. 1936.
6. MEZ, C., and H. ZIEGENSPECK. Der Königsberger serodiagnostische Stammbaum. Bot. Arch. **13**: 483–485. 1926.
7. PRICE, W. C. Local lesions on bean leaves inoculated with tobacco mosaic virus. Amer. Jour. Bot. **17**: 694–702. 1930.
8. RAWLINS, T. E., and C. M. TOMPKINS. The use of carborundum as an abrasive in plant-virus inoculations. (Abstract) Phytopath. **24**: 1147. 1934.

ADDITIONAL STUDIES CONCERNING THE RUST OF IRIS, PUCCINIA IRIDIS[1]

E. B. MAINS

(Accepted for publication Sept. 28, 1937)

In a previous paper[2] 2 races of *Puccinia iridis* (DC.) Walh. were distinguished by the reactions of strains of *Iris fulva* Ker.-Gawl. and *Iris foliosa* Mackenzie and Bush. None of the varieties of bearded *Iris* of the *Pogoniris* section was successfully infected by these 2 races. In 1928 rust was reported on German iris in the vicinity of San Diego, California, but an attempt to obtain material for study was unsuccessful. In 1934 a report was received from M. W. Gardner that rust was severe on certain bearded varieties in a varietal planting of the University of California at Berkeley, Calif. Dr. Gardner kindly furnished material for study, including a selected set of varieties of *Iris,* and generously has allowed the use of his notes concerning varietal differences in the planting at Berkeley.

During the winters of 1934–1935 and 1935–1936 this rust was studied in a greenhouse on a number of varieties and species of *Iris.* At the same time a comparison was made with the race *septentrionalis* (Tables 1–3).

The rust from Berkeley evidently is a distinct race. The name *Puccinia iridis* race *californica* is proposed for it. Table 4 gives a comparison of the 3 races now recognized on differentiating strains of *Iris.*

As shown in table 1, most of the varieties of bearded *Iris* were highly resistant to the race *californica.* Dr. Gardner's notes show that the same was true in the varietal planting at Berkeley. His notes may be summarized as follows. The varieties Ivory Coast, Leonato, San Rafael, Santa Fe, and *I. longipetala* were severely rusted. Blue and Gold, Colusa, Lady Foster, Magnifica, Pale Moonlight, Pluie d'Or, and Santa Barbara were moderately rusted. California Blue, Don Quixote, Fortuna, Mme. Cherie, Oruga, Padre, Purissima, and Shining Water varied from slight to moderate infection. New Albion, Arkansas, Dolly Madison, Elgante, Frieda Mohr, Gold Top, Modoc, San Luis Rey, Sierra Blue, Sitka, Tulsa, Wm. Mohr, Yosemite Falls, *I. douglasiana,* and *I. microsiphon* were slightly rusted. Asia, Easter Morn, El Capitan, Glowing Embers, Pacific, Pink Lass, Senorita, Uncle Remus, and *I. fimbriata* showed only a trace of rust. Ambassadeur, Blue Gown, Bravura, Bronze Beacon, Dream, Estrallon, Fro, Georgia, Hidalgo, Jacqueline Guillot, J. B. Dumas, Monterey, Pastel Shades, Rayo de Sol, Rialgar, Rosado, Rose Mitchell, Small Yellow, and Sun Dew developed no rust.

As shown in table 1, all of the varieties of bearded *Iris* were highly resistant to the race *septentrionalis. I. bucharica* was very resistant to

[1] Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 634. The inoculation experiments were made possible through facilities furnished by the University Botanical Gardens.

[2] Mains, E. B. Host specialization in the rust of *Iris, Puccinia iridis.* Amer. Jour. Bot. 21: 23–33. 1934.

californica and very susceptible to *septentrionalis* (Table 2). Other species and varieties did not show a pronounced difference in reaction to the 2 races (Tables 2 and 3).

TABLE 1.—*Comparison of the reaction of bearded varieties of Iris to races of californica and septentrionalis of Puccinia iridis*

Variety	Reaction to race[a]		Variety	Reaction to race[a]	
	californica[b]	*septentrionalis*[c]		*californica*[b]	*septentrionalis*[c]
Afterglow	0		Monsignor	3	0
Alcazar	0	0	Monterey[d]	0	0
Ambassadeur	0	0	Mother of Pearl	0	0
Asia	0		Mrs. Neubronner	0	0
Aurea	0	0	Mrs. H. Darwin	0	0
Autumn King	0	0	Olive White	0	0
Autumn Queen	0	0	Oriflamme	0	0
Ballerine	0	0	Oruga[d]	2–3	0
Bruno	0	0	Padre[d]	1	0
Caprice	0	0	Pallida Dalmatica	0	0
Celeste	0	0	Parisiana	0	0
Crusader	0	0	Pluie d'Or	1	0
Eleganted[d]	2	0	Powhatan	0	0
Estrallon[d]	0	0	Prairie Gold	0	0
Fairy	0	0	Princess Beatrice	0	0
Flavescens	0	0	Prospero	0	0
Florentina Alba	0–1	0	Purple King	0	0
Georges Tribolet	1	0	Quaker Lady	0	0
Georgia	0	0	Queen Caterina	0	0
Golden Glory	0	0	Queen of May	0	0
Golden Promise	0	0	Rhein Nixe	0	0
Gypsy Queen	0	0	Rialgard[d]	0	0
Hidalgo[d]	0	0	San Luis Rey[d]	1	0
Indian Chief	0	0	San Rafael[d]	2–3	0
Iris King	0	0	Santa Barbara[d]	2	0
Isoline	2	0	Santa Fé[d]	4	0
Jacquesiana	0	0	Sarpedon	1	0
Jean Siret	1	0	Seminole	0	0
Juniata	0	0	Shekinah	0	0
Kochii	0–1	0	Sherwin Wright	0	0
Leonata[d]	0–1	0	Souvenir de Mme. Gaudichau	1–2	0
Lent A. Williamson	0	0	Susan Bliss	1–2	0
Lohengrin	0	0	Tom Tit	1–2	0
Mme. Chereau	2	0	Vesper Gold	0	0
Magnifica	2–3	0	White Knight	0	0
Mary Garden	0	0			

[a] 0, highly resistant, no uredinia; 1, very resistant, few small uredinia; 2, moderately resistant; 3, moderately susceptible; 4, very susceptible; t, trace of rust.

[b] Results obtained with rust from Berkeley, California. Collected by M. W. Gardner.

[c] Summary of results obtained with rust collected on *Iris spuria* at Ann Arbor, Mich., and *I. versicolor* at Trout Lake, Mich., by the writer and on *I. missouriensis* at Pullman, Wash., by G. W. Fischer.

[d] Varieties received from the varietal planting of the University of California through M. W. Gardner.

Susceptible varieties of *Iris* are not limited to any one section of the genus. Both susceptible and resistant strains occur in such diverse groups as the *Apogon* and *Xiphium* sections (Tables 2 and 3). As a group the *Xiphium* section is one of the most susceptible. Several species contain both resistant and susceptible strains. In *I. spuria*, a very variable species, 2

TABLE 2.—*Comparison of reactions of species of Iris to races californica and septentrionalis of Puccinia iridis*

Species of *Iris*	Reaction to race		Species of *Iris*	Reaction to race	
	californica	*septentrionalis*		*californica*	*septentrionalis*
Apogon Section:[a]			*I. giganticoerulae* Small[c]	0	0
Iris douglasiana Herb.	0	0	*I. thomasii* Small[c]	0	0
I. ensata Thunb.	0	0	*I. tyriana* Small[c]	0	0
I. foliosa Mackenzie and Bush (165)[b]	0	0	**Pardanthopsis** Section:		
I. fulva Ker.-Gawl. (32)[b]	0–1	0	*I. dichotoma* Pallas	2–3	3
I. fulva (164)[b]	0	0	**Evansia** Section:		
Dorothea K. Williamson (*I. fulva* × *I. foliosa*) 110[b]	0	0	*I. tectorum* Maxim.	0	0
I. hexagona Walter		0	**Regelia** Section:		
I. pseudacorus L.	0	0	*I. hoogiana* Dykes	4	4
I. macrosiphon Torrey		0	*I. stolonifera* Maxim.		4
I. missouriensis Nuttall		4	*Regeliacyclus* Hybrid Charon	4	
I. purdyii Eastwood		0	*Pogocyclus* Hybrid William Mohr	3	
I. spuria L. (10463)[b]	4	4	**Pogoniris** Section:		
I. spuria (6752)[b]	3	4	*I. chamaeiris* Bertolini	0–2	0
I. spuria (7097)[b]		1–2	*I. mesopotamica* Dykes	1–2	0
I. spuria (12683)[b]	1	0	*I. pumila* L.	0	0
I. unguicularis Poiret	0	0	**Juno** Section:		
I. tenax Douglas	0	0	*I. bucharica* Foster	1	4
I. versicolor L.	0	0	**Reticulata** Section:		
I. chrysophoenicia Small[c]	0	0	*I. histrio* Reichenb.		4
I. elephantina Small[c]	0	0	*I. reticulata* M. Bieb.	2	0–1

[a] Classification of W. R. Dykes. The Genus *Iris*. Cambridge University Press. 1913.
[b] Numbers refer to special strains of the species.
[c] Species received from J. K. Small.

strains were susceptible, one moderately resistant, and one highly resistant. Similar results have previously been obtained with this species for the race *septentrionalis* and *australis*. Also, in previous studies, similar variations were found in *I. virginica* to both *septentrionalis* and *australis*. Varieties of Spanish and Dutch iris (*I. xiphium* and hybrids) show a similar situation to the races *californica* and *septentrionalis* (Table 3). Only one strain each of most of the other species was studied. It is probable that a study of a wider range of strains would show a similar situation in a number of other species. In marked contrast to this is the uniform, high susceptibility of varieties of English iris, *I. xiphioides* (Table 3).

Iris rust in this country has been largely confined to wild species. The discovery of rust on bearded horticultural varieties raises the question whether it may be of importance on cultivated forms. Although the race

TABLE 3.—*Comparison of the reactions of varieties belonging to the Xiphium Section of the genus Iris to races californica and septentrionalis*[a] *of Puccinia iridis*

Variety	Reaction to race		Variety	Reaction to race	
	californica	*septentrionalis*		*californica*	*septentrionalis*
Iris xiphium and hybrids (Spanish and Dutch)			Queen Wilhelmina	2	1
A. Bloemand	4		Rembrandt		3
Abraham Storck	t		S. Roombout	1	3
Adrian Backer	2	2	S. Van Rujdard	4	
Bell Chinoise		0–1	Theresa Schwartz	1	1
Cajanus	0–1	0[b]	Theodore de Boek	2	2
Celestial	1		Van Everdinger	0–1	2
David Bliss	t	0	Wedgewood	1	0–1
David Haring	4	4	White Excelsior	3	3–4
Dirk Dalens	0		W. Versehuur	1	
Dr. Haring	4		W. Zuiderveld	4	
E. B. Garnier	2	2	Yellow Queen	3	2–3
Frans Hals	4		*I. xiphioides* (English)		
Golden Bronze	4		Almona	4	
Golden Glory	3	3	Cornelia	4	4
Hobbema	2		Grant	4	4
Huchtenberg	4	4	Herman	4	4
Imperator	0	0	Mauve Queen	4	4
King of Blues	0	0	Mont Blanc	4	4
King of Whites	4	4	Perle des Jardins		4
Leonardo da Vinci	4		Prince Albert	4	4
Poggenbeeck	4	3–4	Prince of Wales		4
Prince Henry	3	2–3	Queen of the Blues	4	4
Queen Emma		4	Raphael	4	
			Sweet Lavender	4	4

[a] Frank P. McWhorter kindly supplied a number of the varieties for this study.

[b] This variety was reported as susceptible (Am. Jour. Bot. 21: 29, 1934). Apparently the material studied was incorrectly named.

californica severely infects some bearded varieties, most are highly resistant. If susceptible varieties should, however, be used extensively in breeding new varieties, the rust might become an important factor for growers of this group. It would be interesting to know the ancestry of the susceptible varieties. It may be that susceptibility was introduced from some other section, possibly through *Pogocyclus* hybrids.

Some breeders are giving considerable attention to several of the wild species, and are selecting and naming special strains for garden plantings. There is a possibility that some of these may prove susceptible to one or more of the rust races. This is specially true for those species of the *Iris spuria* type.

TABLE 4.—*Reaction of differential strains of Iris to three races of Puccinia iridis*

Iris strain	Reaction to race		
	californica	*septentrionalis*	*australis*
Iris fulva (32)	0–1	0–1	4
I. fulva (164)	0	0–1	4
I. foliosa (165)	0	0	
Leonato	4	0	
Santa Fe	4	0	

In the *Xiphium* section the rust might occasionally become important for growers if a source of inoculum should occur on wild species during the growing season near plantings. In the midwest, however, the bulbose varieties usually mature before much rust has developed on wild species.

SUMMARY

A rust of bearded *Iris* at Berkeley, California, is an unnamed race for which the name *Puccinia iridis* race *californica* is proposed (Table 4).

Most of the varieties of bearded *Iris* are highly resistant to race *californica*, and all those studied were highly resistant to race *septentrionalis* (Table 1).

All the varieties studied of English *Iris* were very susceptible to races *californica* and *septentrionalis* (Table 3).

Among the Spanish and Dutch *Irises* the varieties Cajanus, David Bliss, Imperator, King of Blues, and Wedgewood were outstanding for resistance to both *californica* and *septentrionalis* (Table 3).

PHYTOPATHOLOGICAL NOTES

Blueberry Galls Produced by the Fungus Phomopsis.—Galls on the stems of cultivated blueberry plants have in the past been attributed to several agencies, including insects, winter injury, and particularly the crown-gall organism. From investigations at this station, however, it was found that the most common type of blueberry gall is caused by a fungus. The galls occur at the crown and along the stem. At first small dark slits appear in the stem, from which lighter colored nodular growths emerge, eventually protruding 5 mm. to 3 cm. or more (Fig. 1, A and B). They resemble much the overgrowths caused by the crown-gall organism. When older, the outgrowths become dark colored. The following year more galls may appear on the stem in late July, or August, and in time kill the stem. These galls develop and spread rather slowly and several years may elapse between the appearance of the first gall and the death of the stem. The disease occurs principally in those regions where the cultivated blueberries are grown, *i.e.*, Massachusetts, New Jersey, Oregon, and Michigan. The Cabot and Pioneer varieties, so far as known, are the ones that are most susceptible to the disease. Because these outgrowths were found to be spreading in some of the localities where blueberry culture was commercially important, it became urgent to learn definitely the cause of the disease.

Platings on beef agar made from young galls gave an organism thought at first to be crown gall, but inoculations into blueberry stems and other plants susceptible to crown gall made with these fresh isolations failed repeatedly. These attempts were made both in the fall and the following spring. Later, the organism was identified as *Bacillus radiobacter*, which resembles strikingly the crown-gall organism. No other bacterial organism appeared on the plates in sufficient numbers to be considered a possible patho-

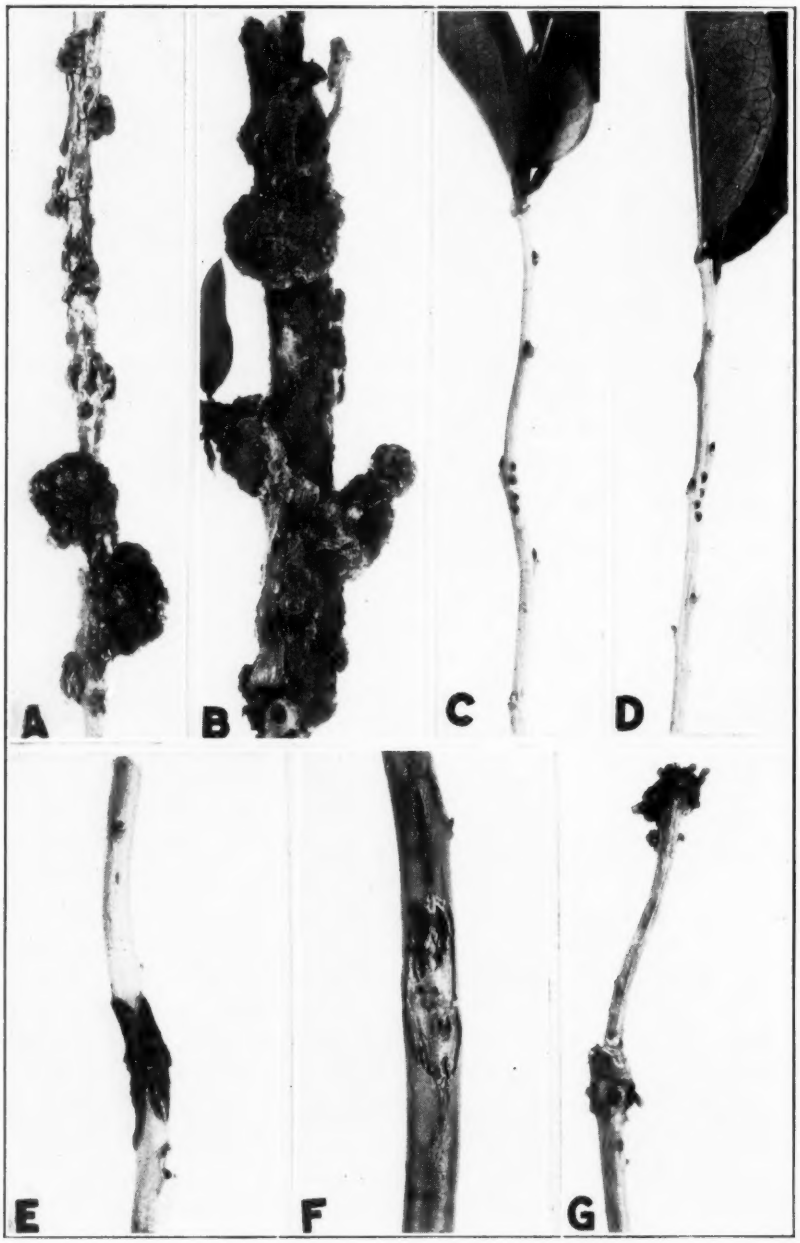

FIG. 1. A and B. Galls on naturally infected cultivated blueberry. A. From New Jersey. B. From Massachusetts. C and D. Inoculations into cultivated blueberry stems, with two strains of *Bacterium tumefaciens*, on 5–12–37. Photographed on 9–21–37. Negative results. E. Inoculation into cultivated blueberry plant, with New Jersey isolation of *Phomopsis*, on 5–12–37. Photographed on 9–21–37. F. Inoculation into cultivated blueberry, with Massachusetts isolation of *Phomopsis*, on 5–12–37. Photographed on 9–21–37. G. Inoculation into *Viburnum opulus* with Massachusetts *Phomopsis*, on 5–16–37. Photographed on 8–24–37. All × 1.

gen. Further evidence that the organism isolated was not *Bacterium tumefaciens* was obtained by inoculating with various strains of *Bact. tumefaciens* into young shoots of cultivated blueberry plants to see if one or more might be infectious (Fig. 1, C and D). The peach, raspberry, hop, and dahlia strains were used. There was some evidence that one of the strains of *Bact. tumefaciens* caused a canker-like reaction in tender blueberry stems but it proved to be of limited extent, as the lesion soon healed over.

In the study of the galls no fungus fruiting-bodies were found on any of those examined and very little fungus mycelium could be detected by microscopic examination of young galls. Nodular galls whose soft tissues necrose or die quickly offer a ready foothold for various saprophytes, so that isolation of the pathogen is difficult. This difficulty, however, was overcome by rather long sterilization of the surface of the galls in mercuric chloride 1–1000, then making and later comparing hundreds of tube cultures. By this method many pure cultures of the fungus *Phomopsis* from various lots of material were obtained. Its pathogenicity was proved by inoculation into cultivated blueberry plants under greenhouse conditions favoring rapid growth. With moist conditions while the fungus was getting established, followed by rather dry conditions, over 50 per cent of the inoculations with both Massachusetts and New Jersey isolations produced outgrowths (Fig. 1, E and F). *Phomopsis* was isolated also from galls obtained from Oregon blueberry plants. It should be noted that the *Phomopsis* isolated from galls on blueberry is not the same one that produces stem-tip blight of blueberry.

Jasminum nudiflorum and *Viburnum opulus,* whose tissues do not harden so readily as those of the blueberry, were also used as host plants for the blueberry *Phomopsis,* and on these plants galls formed more quickly and, in some instances, roots were formed in addition to galls (Fig. 1, G). Root formation was not observed on blueberry stems. Both *Jasminum* and *Viburnum* are attacked by a gall disease somewhat resembling the blueberry gall in appearance and in both cases produced by a *Phomopsis.*[1, 2]

A few serious outbreaks of this disease have occurred, but these have been traced to carelessness in rooting cuttings from diseased plants. If reasonable care is taken in propagating blueberries from disease-free plants, there is not much danger of spreading the disease. By persistent effort, the disease can be eradicated as has been done in public parks in the case of the gall disease of *Viburnum* by removing and burning all infected parts in the autumn, when the overgrowths can be readily seen. This method of eradication can be followed with the blueberry.—NELLIE A. BROWN, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

Elsinoë on Lemon Fruits from Paraguay.—What is regarded now as *Elsinoë australis* Bitancourt and Jenkins, the cause of sweet orange fruit

[1] Brown, Nellie A. A fungus gall on viburnum mistaken for crown gall. Phytopath. **24**: 1119–1120. 1934.

[2] Privet and jasmine galls produced by a species of *Phomopsis.* Phytopath. **26**: 795–799. 1936.

scab, has been found in its conidial (*Sphaceloma*) stage on 2 New York importations of lemon fruits (*Citrus limonia* Osb.) recently received from San Lorenzo, Asunción, Paraguay, the principal citrus-growing dstrict of that country (Fig. 1). The identification was made on the basis of 2 fruits intercepted on May 14 from the first importation (Port of N. Y. 71218) by Inspector G. J. Nicholaïdes and from one fruit taken from

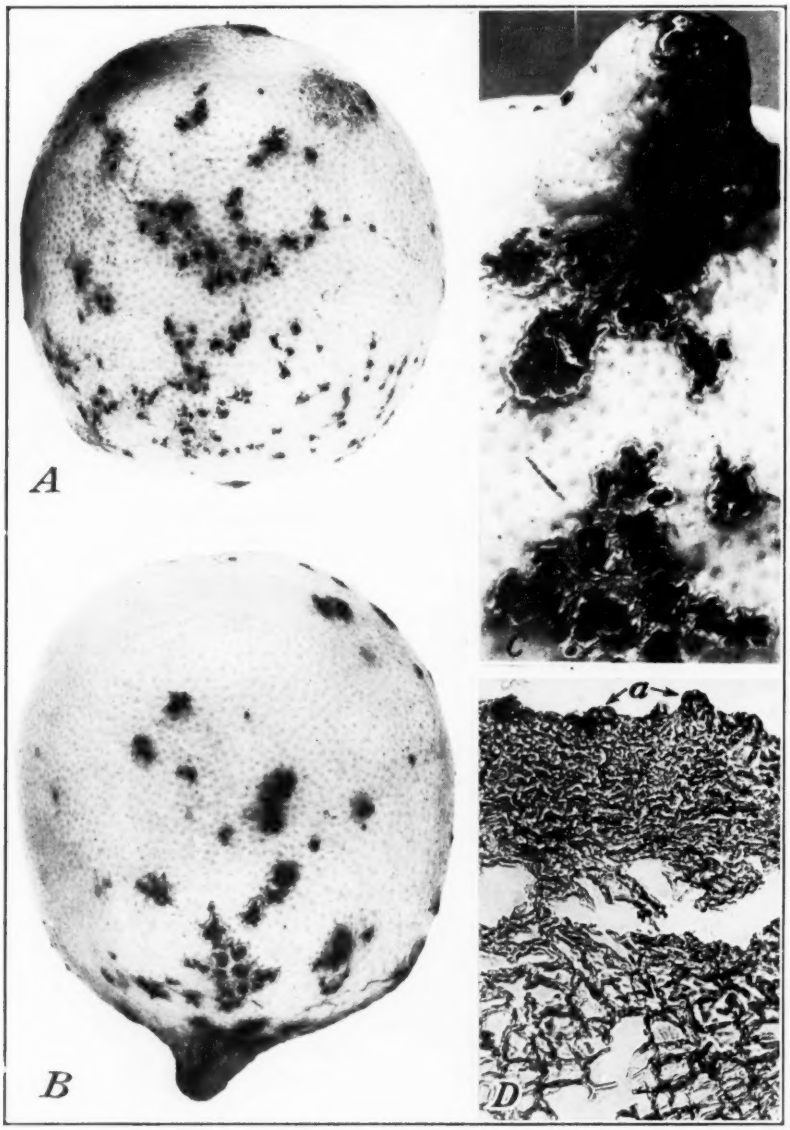

FIG. 1. *A* and *B*. *Elsinoë* on lemons from Paraguay, intercepted at the port of New York, on May 14 (*A*) and May 22 (*B*), 1937. ×1. *C*. Enlargement of lesions from *B*. ×3. *D*. Small acervuli on lesion.

the second importation (Port of N. Y. 71326) and intercepted by Inspectors R. A. Fox and E. Kostal. The severely diseased and exceptionally unattractive appearance of the rind also was noted by C. O. Bratley, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, who saw the importations. The distinctive lesions are chiefly burnt sienna in color. The intercepted fruits were severely affected and in the second shipment the infection was recorded as general. The plant quarantine records show that the only previous importation (July, 1936) was disease-free, as was learned from Max Kisliuk, in charge of Plant Quarantine Inspection at New York.

In their recent study of sweet orange fruit scab, Bitancourt and Jenkins[1] made every effort possible to obtain any available information that might be interpreted as applying to the history and distribution of sweet orange fruit scab in South America. Balansa's classic mycological herbarium specimen of what is now regarded as *Elsinoë australis* on sweet orange from Paraguay (1882), was, of course, known, but not the susceptibility of lemon to attack by what appears to be the same fungus.

The identification of the organism on lemons from Paraguay in May was immediately confirmed by letters from H. S. Fawcett, of the California Station, and A. A. Bitancourt, of the Instituto Biologico, São Paulo, Brazil, telling of their visit to Paraguay in April, and of observing and gathering lemons in the same locality, affected by what they also considered to be *Elsinoë australis*.

This fungus, which causes a scab of sweet orange fruit in South America, has so far not been found in the United States. Consequently, its appearance on lemon fruits imported for sale in our markets constitutes a new and important source of danger to our citrus-growing industry. The fungus was isolated and cultured from the imported fruit and its viability thereby proved. An isolation of the fungus had been made in March, from sour orange (*Citrus aurantium* L.) collected September 1936, in Argentina, by Mr. G. L. Fawcett, of the Estacion Experimental Agricola, at Tucumán, as well as previously (1934) from a sweet orange several weeks after it had been intercepted at New Orleans.—ANNA E. JENKINS, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

An Elsinoë causing an Anthracnose on Hicoria pecan.—An *Elsinoë* was discovered on *Hicoria pecan* (Marshall) Britton at Campinas, São Paulo, Brazil, on May 20, 1937, by A. S. Costa and J. M. Salles, Instituto Agronomico de São Paulo, Campinas. Specimens, together with a photomicrograph of the perfect stage, were contributed by Costa. Isolations from ascospores made on May 31 and from acervuli on June 1 yielded slow-growing compact cultures. From Rand's[1] discussion of an imperfect fungus found on pecan in the United States, provisionally iden-

[1] Bitancourt, A. A., and Anna E. Jenkins. Sweet orange fruit scab caused by *Elsinoë australis*. Jour. Agr. Res. [U. S.] **54**: 1–18. 1937.

[1] Rand, F. V. Some diseases of pecans. Jour. Agr. Res. [U. S.] **1**: 303–337. 1914. (Nursery blight, pp. 305–312.)

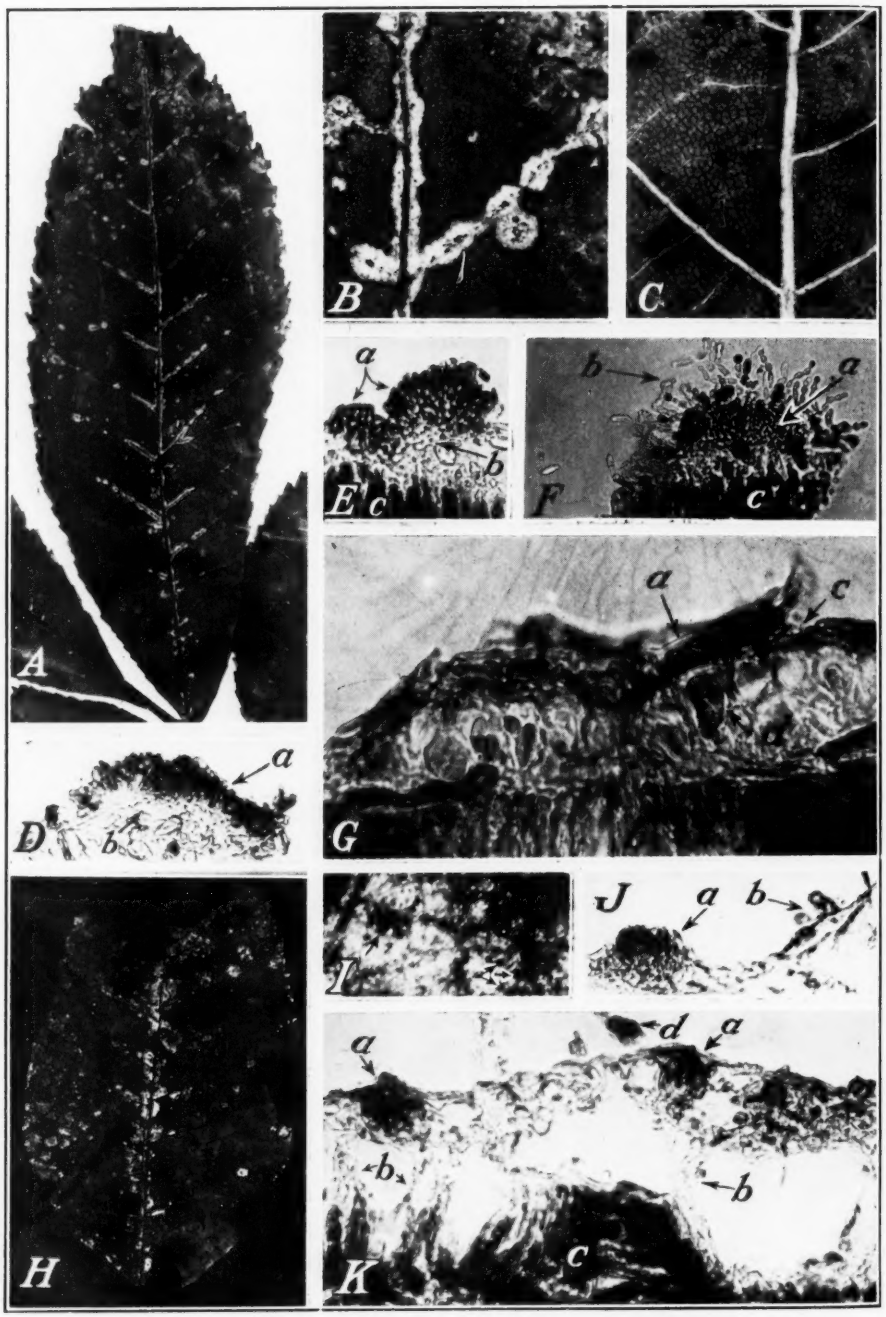

FIG. 1. *A. Elsinoë randii* on upper leaf surface of *Hicoria pecan*, São Paulo, May 20, 1937. ×1. *B.* Part of *A*, showing acervuli and ascomata; *C*, reverse of *B*. Both ×5. *D* and *E*. Acervuli: *a*, conidiophore palisades; *b*, underlying stromata; *c*, palisade leaf tissue. *D*, ×250; *E*, ×300. *F*. Section of acervulus (*a*) cultured 24 hours on potato-dextrose agar droplet showing the conidia produced, these mostly germinated (*b*); (*c*) palisade leaf tissue. ×200. *G*. Contiguous ascomata: *a*, disrupted epidemis; *b*, palisade leaf tissue; *c*, epithecium; *d*, ascospores. ×500. Photomicrograph contributed by A. S. Costa. *H–K*. *Sphaceloma* on mycological herbarium specimens of pecan leaves from (*H*) Georgia, Oct. 23, 1911, and (*I*, *J*, *K*) Mississippi, Oct. 22, 1928. *I*; *J*, *a*; *K*, *a*, acervuli; *K*, *b*, hyphae; *K*, *c*, leaf palisade; *J*, *b*, and *K*, *d*, probably swollen conidia. *H*, ×1; *I*, ×25; *J*, ×250; *K*, ×350.

tified as *Phyllosticta caryae* Pk., the writers had earlier considered this to be the conidial stage (*Sphaceloma*) of an *Elsinoë*. The new ascomycete from Brazil is the perfect stage of the organism isolated and studied by Rand, or else it is closely related. It is proposed to name it in honor of Doctor Rand, who made a careful study of what is now known to be *Sphaceloma*, growing on pecan in its native home, illustrating cultures and also the effect on leaves. A technical description follows:

Elsinoë randii sp. nov.

Produces cinereous areas on upper leaf surface, sometimes with purplish to black margins, often penetrating leaf as brown to black discolorations; spots round or irregular, .5–5 mm. in diameter, outlining midrib and veins or occupying area between veins of leaflet; ascomata epiphyllous, round or oval, sometimes irregular, pulvinate, 80–200 μ in diameter, dark brown to black, formed intraepidermally, covered with external disrupted epidermal walls and lying directly on palisade layer of host, 50–120 μ thick, with hyaline light brown pseudoparenchyma containing scattered or crowded embedded asci and covered with darker epithecium; asci globose to egg-shape, walls thick, 14–21 μ in diameter, containing 4 to 8 hyaline, 3-septate ascospores, constricted at middle septum, 6–8 μ × 11–16 μ.

Sphaceloma stage: Acervuli epiphyllous, round or irregular, intraepidermal, erumpent-superficial, up to 50–150 μ in diameter, yellow, brown, or black, compact, sometimes almost entirely pseudoparenchymatous with dark crowded conidiophores apparently coalesced, 15–50 μ thick, underlying plectenchyma scanty, hyaline; conidia (in culture) hyaline, continuous or 1-septate, 4–5 μ × 8–15 μ. (Fig. 1, A–G and Fig. 2).

Areas superne cinereas, saepe atro-marginatas, inferne discolorentes, in foliis producens; maculis variis, rotundis vel irregularibus, usque 5 mm. in diam., nervisequentibus vel nervis limitatis; ascomatibus epiphyllis, fusco-brunneis, rotundis vel irregularibus, pulvinatis, 50–120 μ crassis; ascis globosis ovatisve, 14–24 μ in diam., 4–8-sporis; ascosporis 3-septatis, 6–8 × 11–16 μ; acervulis epiphyllis, rotundis vel irregularibus, 50–150 μ in diam., 15–50 μ crassis; conidiis (in culturis) continuis vel bicellularibus, 4–5 × 8–15 μ.

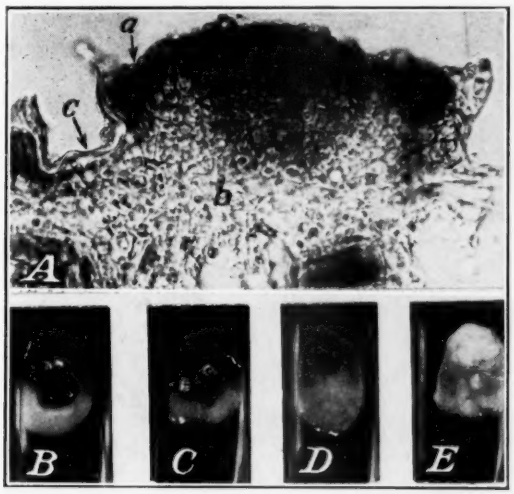

FIG. 2. *Elsinoë randii*. *A*. Acervulus: *a*, conidiophore palisade; *b*, underlying stroma; *c*, ruptured epidermis, São Paulo, May 20, 1937. × 500. *B* and *C*. Original cultures from acervuli. *D* and *E*. From ascospores, all after about 30 days on a modified Thaxter potato-dextrose agar medium. × 1.

On leaves of *Hicoria pecan* (Marshall) Britton, from Campinas, São Paulo, causing pecan anthracnose, May 20, 1937, A. S. Costa and J. M. Salles (type, in Mycological Collections of the Bureau of Plant Industry (No.

72591), Phytopathological Herbaria of Instituto Biologico (No. 2665) and of Instituto Agronomico, (2075), São Paulo). An earlier specimen was collected at Campinas on July 12, 1935, by Costa (Phytopath. Herb. Inst. Agron. No. 1040 and Inst. Biol. No. 2776). Additional specimens examined of the same or a closely related fungus from the United States: Cairo, Ga., Aug. 28 and Oct. 23, 1911, F. V. Rand (Fig. 1, *H*); Washington, D. C., Jan. 1, 1913, F. V. Rand (infection from artificial inoculation); Ovett, Miss., Oct. 22, 1928, C. S. Bentley, communicated by L. E. Miles, October, 1928, to the Plant Disease Survey for identification of the fungus (Fig. 1, *I–K*); Gainesville, Fla., Sept. 29, 1937, W. B. Tisdale.—ANNA E. JENKINS and A. A. BITANCOURT, Bureau of Plant Industry, Washington, D. C., and Instituto Biologico de São Paulo.

Gill Fungi Associated with the Roots of Cereals.[1]—*Pholiota dura* (Bolt.) Fries, *P. praecox* (Pers.) Fries, *Naucoria* spp. and a number of small, deli-

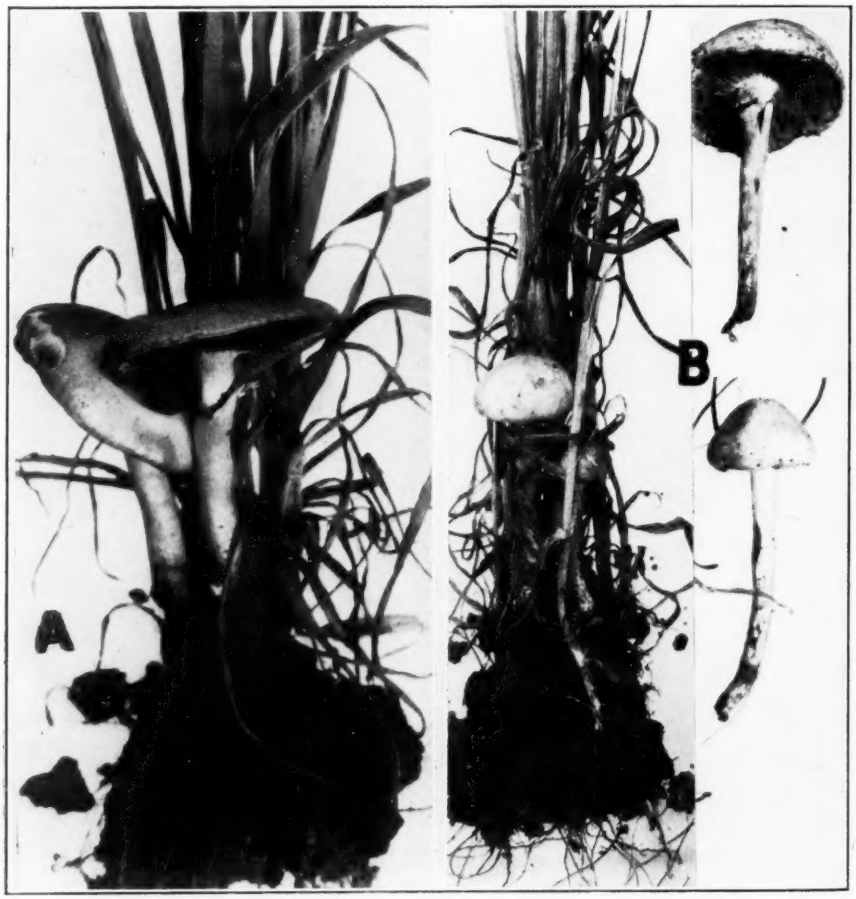

FIG. 1. A. *Pholiota praecox* at the base of oat plants (*Avena sativa*). B. *P. dura* at the base of wheat plants (*Triticum aestivum*). Both collected 7 miles southwest of Lebanon, Oregon, May 1, 1934.

cate, undetermined Agaricales have been found attached or associated with the crowns of oats, barley, and wheat in western Oregon (Fig. 1). The white rhizomorphous mycelium of these fungi causes shredding and decay of necrotic and dead leaf sheaths and even at times appears to enter the outer cortical cells of the roots. It has been suggested that these fungi might be parasitic on the cereals.

Several isolations were made during 1930–33 from coarse mycelium attached to wheat and barley plants in the vicinity of Corvallis, Oregon. This mycelium was basidiomycetous in nature, and in one case was attached to immature gill fungi. This latter culture was grown on wheat grain inoculum and introduced into soil, in the greenhouse, in which winter cereals were growing. In all cases over a period of four years wheat, oats, barley, rye, and einkorn were not adversely affected by the fungus; in fact, the inoculated plants were always taller and and stronger than the noninoculated ones.

In 1934 pure-culture isolations were readily obtained from *Pholiota dura* and inoculations again made in the greenhouse. *P. dura* also was nonpathogenic to the cereals and appeared to be mildly beneficial. Data of the investigations are filed in unpublished reports.—RODERICK SPRAGUE, Oregon State College, Corvallis, Oregon.

---

[1] Coöperative investigations by the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the Oregon Agricultural Experiment Station. Published as Technical Paper No. 273 of the Oregon Agricultural Experiment Station.